SANTA CLARA VALLEY WATER DISTRICT

LLAGAS GROUNDWATER BASIN NITRATE STUDY

NITRATE DATA REVIEW

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LLAGAS GROUNDWATER BASIN NITRATE STUDY

CONTRACT NO. 1-053-250-0

Prepared by

Todd L. Anderson	Assistant Civil Engineer
Michael E. McDonald	Associate Civil Engineer

under the direction of

Belinda A. Allen
Supervising Engineer
Groundwater Protection Division

David J. Chesterman Principal Engineer Groundwater Quality Branch	Roger B. James Operations and Water Quality Manager

AUGUST 1993

PROPERTY OF SANTA CLARA VALLEY
WATER DISTRICT
5750 Almaden Expressway
San Jose, California 95118

R9396

This project has been funded wholly or in part by the United States Environmental Protection Agency using Section 205(j) grant funds under Assistance Agreement C6009585-91-1 to the State Water Resources Control Board and by Contract No. 1-053-250-0 in the amount of $33,823 to conduct a water quality management planning study to develop recommendations for prevention and control of nitrate in the Llagas Groundwater Basin. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the State Water Resources Control Board, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use.

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I. EXECUTIVE SUMMARY

Communities in the southern portion of Santa Clara County rely solely on groundwater from the Llagas Basin for their water supply. Over the years, groundwater from municipal and private water supply wells has been found to contain nitrate levels greater than the levels allowed by federal safe drinking water standards. These standards allow no more than 45 parts per million (ppm) of nitrate measured as nitrate in drinking water. Higher levels have been known to cause adverse health effects in infants. The affected municipal water supply wells are either no longer used or the groundwater from them is blended with other lower nitrate level groundwater from other wells to meet drinking water standards. Some of the private wells are using wellhead treatment systems.

The Santa Clara Valley Water District (District) is responsible for managing the groundwater basin to ensure its viability as a long term potable water supply. The District, as well as other local agencies, is concerned with the elevated nitrate levels in Llagas Basin and, as a result, is conducting the Llagas Basin Nitrate Study. The study will examine previously collected nitrate level data, will collect new data on the occurrence of nitrates and will develop alternative strategies for reducing nitrate levels in the Llagas Basin. Results of the study will help determine whether a water treatment plant or additional recharge ponds should be considered to continue providing a water supply that meets safe drinking water standards to the south Santa Clara County region.

As a part of the Llagas Basin Nitrate Study, a Technical Advisory Committee (TAC), comprised of members of the community, will assist in developing a Nitrate Management Plan (Management Plan) in order to prevent and control the occurrence of nitrate in the basin.

The study will be performed in the following phases: 1) review of historic nitrate data, 2) identification of categories of nitrate sources, 3) sample collection, 4) evaluation of results, and 5) development of Nitrate Management Plan. This "Review of Historical Nitrate Data" report summarizes the first phase of the study. It contains an evaluation of the nitrate data which was generated from previous studies. The overall nitrate study is scheduled for completion in June 1994.

This executive summary is organized to present key information about:

1. Basin groundwater flow, also known as hydrogeology;
2. Changes in nitrate levels;
3. Known locations of high nitrate levels;
4. Limitations of the data review;
5. Evaluation of existing information.

LLAGAS BASIN GROUNDWATER FLOW

The Llagas groundwater basin has two hydrogeologic regions. One region is referred to as the forebay region, where rainfall and District artificially recharged water percolates through the ground directly into the underlying aquifer. The forebay region is located in the northern part of the Llagas basin. The second region is known as the confined region, where a thick clay layer known as an aquitard separates the deeper water producing aquifers from the shallow ones. Groundwater on top of this clay layer is primarily from rainfall, whereas groundwater flowing underneath the clay layer primarily orginates in the forebay region. There is some vertical interconnection between these aquifers through old wells that may be screened in both shallow and deep aquifers.

The direction of groundwater flow in the Llagas basin is primarily south towards the Pajaro River. Due to the variable characteristics of the basin, the depth to ground water below ground surface differs throughout the basin and normally ranges from between 10- to 70-feet below ground surface.

CHANGES IN NITRATE LEVELS

Groundwater samples from a total of 492 groundwater wells were collected during seven previous studies. The water quality data for these samples were reviewed to determine changes in nitrate occurrence in groundwater over time. Six of these wells were selected as representative example wells and were used to evaluate whether there are long-term changes in nitrate levels. These six example wells were selected as representative because they had been most frequently sampled from approximately 1957 to 1978 and are located throughout the Llagas Basin. Nitrate levels in these wells fluctuated from year to year, but there appears to be a gradual increase in nitrate levels from 1957 through 1978.

LOCATIONS OF HIGH NITRATE LEVELS

In order to identify spatial patterns of nitrate contamination in the basin, all 492 wells were divided into four categories based on the highest historical nitrate level found in each well. The four categories are listed below and the number and percentage of the 492 wells is noted for each category:

- Category A—25 to 45 ppm, 214 wells (43 percent)
- Category B—45 to 70 ppm, 178 wells (36 percent)
- Category C—70 to 100 ppm, 77 wells (16 percent)
- Category D—greater than 100 ppm, 23 wells (5 percent)

Wells in categories A and B were located throughout the basin. Wells in categories C and D, those with higher levels of nitrates, appeared to be clustered more toward the southern end of the Llagas Basin in the confined region.

LIMITATIONS OF THE DATA REVIEW

Three main limitations for use of the past sample results were found and affected the data review. The first limitation is the lack of well construction information, such as well screen locations. Most water supply wells are screened at several different depths below the ground surface in order to maximize the water production from the well. Nitrates may be entering the well at various depths and the resulting well water sample does not represent any one particular aquifer. In addition, the concentration actually present in one aquifer may be significantly diluted by less contaminated water in the other aquifers from which the well draws water. The data was still considered useful for purposes of evaluating spatial patterns and long-term trends of nitrate contamination.

A second limitation is that previous sample collection techniques may have differed from study to study. The different sample collection procedures could produce a nitrate level value which may be higher or lower than the actual level present in the groundwater aquifers. This analysis recognizes that the levels reported by the different studies may vary.

A third limitation is that there is very limited depth to groundwater information for most of the wells. A rise or fall in the depth to groundwater throughout the seasons and years could theoretically cause nitrate concentrations to vary. This is due to nitrates in soil dissolving into groundwater when the groundwater rises. However, variations in depth to groundwater did not appear to impact nitrate levels. It was found that there could be an increase in nitrate levels associated with either a rise or fall in depth to groundwater.

EVALUATION OF EXISTING DATA

Based on the data reviewed for this study, nitrate levels in groundwater appears to have gradually increased from 1957 through 1978. The highest nitrate levels are found in the southern portion of the Llagas Basin. Of the 492 wells from which sample results were reviewed, wells which contained nitrate levels less than 70 ppm appeared to be located throughout the Llagas Basin, whereas wells which contained nitrate levels greater than 70 ppm appeared to be clustered toward the southern end of the Llagas Basin.

This phase of the study is limited to evaluating only the ground water quality results from past studies. Future phases of study will provide additional results which will be used to develop nitrate management strategies and to prepare an overall study report.

II. INTRODUCTION

The Llagas Groundwater Basin Nitrate Study is being conducted by the Santa Clara Valley Water District with partial funding from the State Water Resources Control Board (SWRCB) to determine the extent and sources of nitrate contamination present in the Llagas Basin of Santa Clara County. The study is being conducted because the District has observed a general trend of continuing increases in nitrate levels in groundwater in the Llagas Basin. The purpose of the study is to aid in developing and recommending an implementation plan for the prevention and control of nitrates in the basin.

The southern part of Santa Clara County, including the cities of Morgan Hill and Gilroy and the area of San Martin, depends solely on the Llagas Groundwater Basin for its drinking and irrigation water supply. Current land use patterns in the Llagas Basin Area include about 40 percent total agricultural, 25 percent Urban Service Area, 20 percent Rural Residential area, and 5 percent parks and open space. The remaining 10 percent is miscellaneous, such as Public Transportation, Educational/Institutional, and Public Facilities. Considerable population growth in southern Santa Clara County is expected as the agricultural areas are experiencing increasing urbanization. This trend not only impacts water demands in the region but also affects the rate of nitrate loading to the groundwater basin.

This report represents the completion of the fourth of eleven tasks of which the study is comprised. The previous completed tasks included conducting a public meeting and developing a Quality Assurance Project Plan. The remaining tasks will include identifying possible source areas of nitrate loading, sampling and analyzing groundwater in the vicinity of the source areas, and developing a plan for prevention and control of nitrates. A review of existing and potential legislative mechanisms for controlling nitrates will be performed by a Technical Advisory Committee (TAC).

The District will coordinate this study with the SWRCB, the Central Coast Regional Water Quality Control Board, the Cities of Gilroy and Morgan Hill, and the County of Santa Clara. In addition, a Technical Advisory Committee will provide comment on a Llagas Basin Nitrate Management plan to be developed. Task 4 of the District and SWRCB agreement requires review of historical nitrate data for the study. The purpose of the review is to determine whether an increasing or decreasing trend of nitrate distribution can be established and to identify and examine areas with concentrations of nitrate which exceed federal primary and secondary drinking water standards or exceed basin plan water quality objectives.

This report is organized to provide: (1) introduction, (2) a description of the hydrogeology of the Llagas Basin, (3) existing data review, (4) an evaluation of nitrate concentration trends, (5) a description of how the nitrate distribution maps were developed, and (6) a summary evaluation. Please note that throughout the text, maps, and graphs of this report, nitrate concentration is expressed in ppm as nitrate, unless otherwise noted. The final study report is scheduled for completion on June 30, 1994.

PROJECT DESCRIPTION

This portion of the Llagas Groundwater Basin Nitrate Study includes a review and summary of past studies conducted in the Llagas Basin addressing nitrate contamination in groundwater. The seven previous studies reviewed, as listed in Section IV, included data from approximately 600 groundwater supply wells over the last 35 years in the Llagas basin. Of the 600 wells, 492 of them had nitrate concentrations greater than 25 ppm, and were tallied for this report. Of the 492 wells, 143 of them were used to generate the maps which are attached as Figures 10 through 13, and discussed later in this report.

The data from these previous studies is compiled, assessed, and summarized in this report. The data has revealed trends which will be useful for planning purposes and to help focus control strategies on significant contributors of nitrate contamination to the basin.

In order to simplify presentation and data analysis for the purpose of this study, the data has been divided into four ranges of nitrate concentrations. Two example wells were selected from the first two categories, and one from the last two categories to represent trends. These example wells were selected based on the large number of samples obtained over time so that possible trends may be recognized.

NITRATE HEALTH EFFECTS

In the Llagas Basin, numerous wells have exceeded the federal Maximum Contaminant Level (MCL) of 45 ppm. Nitrate concentrations exceed 100 ppm at several locations. Elevated nitrate concentrations are of concern in that some of the health effects may include methemoglobinemia in infants (blue baby syndrome), cancer, and birth defects. The carcinogenicity (tendency to cause cancer) and teratogenicity (tendency to cause fetal malformations) hazards of nitrates, however, are still being studied. The health effects of nitrates in drinking water are discussed in the October 1988 SWRCB Report No. 88-11, "Nitrate in Drinking Water Report to Legislature," prepared by the Division of Water Quality.

PROJECT LIMITATIONS

There are several limitations of this project that are important to note. First, specific well construction data was unavailable for many of the wells which were sampled because many of the existing wells were drilled before drilling logs were required. This lack of important information has limited the District in drawing conclusions regarding the vertical extent of nitrate distribution in groundwater. References to nitrate concentrations in this survey are not necessarily indicative of the nitrate concentration in a specific aquifer, but rather represent all of the aquifers at which the well is perforated. This "averaging" effect of the well tends to underestimate actual concentrations that may be present in any single aquifer. Second, due to the laminar nature of groundwater flow, turbulent mixing and vertical mixing between aquifers is limited. A third limitation that the reader should note is the possibility that sampling techniques varied between studies. Items such as well purging, sample collection method, sample holding time, and laboratory QA/QC procedures may affect the comparison of results. Sample holding time is more significant for wastewater, where abundant organic matter reduces the nitrate concentrations. In groundwater the holding time is not as significant, but may still result in slightly underreported nitrate concentrations.

OVERALL STUDY TASKS AND STATUS

The study started on October 1, 1991, and is scheduled to be completed on June 30, 1994. Under an agreement between the SWRCB and the District, the following work will be performed by the District during the study according to individual tasks as follows. Please note that three of the tasks have already been completed:

- Manage and Administer Project. This is an ongoing task.
- Conduct Public Participation Meetings. One out of two meetings has been held.
- Develop Quality Assurance Project Plan. This task has been completed.

- Review Historical Nitrate Data[*]
- Identify Nitrate Source Areas
- Select Sampling Points
- Collect and Analyze Samples and Data
- Review Legislative Mechanisms and Management Plan to Control the Nitrate Problem
- Prepare Implementation, Institutional, and Financial Plans
- Prepare Draft Final Report
- Prepare Final Report

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[*] Present status of study

III. LLAGAS BASIN GEOLOGY AND HYDROGEOLOGY**

The geologic history of the Llagas basin has resulted in a complex hydrogeologic system comprised of confined and unconfined aquifers. The Llagas Basin continues southeasterly from the southern end of Coyote Valley at the interconnecting topographic divide to the southern boundary of the County at the Pajaro River as shown in Figure 1. The bulk of the alluvial materials washed into the basin is alluvial fan materials from Coyote Creek splaying southward from the topographic divide. Other major sources of alluvial fill material that comprise the basin are from the Llagas Creek and Uvas Creek from the Santa Cruz Mountains which bound the west side of the basin. Small alluvial fans from small ephemeral drainages occur along both elevated lateral edges of the basin. The depth of alluvial fill and the underlying Santa Clara formation varies from about 500 feet at the northern divide to greater than 1,000 feet at its south end as shown in Figure 2. The Purissima Formation is, in part, water bearing in neighboring counties but is not tapped here.

In general, the basin is divided into three hydrographic units as shown in Figure 1. The northern portion of the basin and the elevated lateral edges of the basin constitute the forebay and the southern flat interior portion is divided into upper and lower aquifer zones (similar to the Santa Clara Valley Basin).

The forebay is comprised mostly of aquifer materials with discontinuous aquitards. Here groundwater occurs unconfined and this zone comprises the principle basin recharge zone. Recharge is from subsurface inflow from Coyote Valley where a groundwater mound occurs beneath the topographic divide, from deep percolation of streams, principally along Llagas Creek to Rucker Avenue, and Uvas Creek to U.S. Highway 101, rainfall irrigation returns, and a lesser amount from the subsurface flow from nonwater-bearing formations that laterally bound the basin. Within the forebay groundwater generally flows from the topographic divide southeasterly down the basin toward the flat south central part of the basin.

Upper and lower aquifer zones occur in the flat southern interior portion of the basin and continue southerly past the County line into the Hollister Basin. The division between the upper and lower aquifer zone is formed by a continuous regional aquitard that occurs at varying depths from about 20 to 100 feet, extending southerly from Rucker Avenue. The thickness of this uppermost major aquitard varies from about 40 to 100 feet. Both upper and lower zones are stratified with aquifers and aquitards.

Groundwater in the upper aquifer zone occurs unconfined in the uppermost aquifer and confined or partially confined in the aquifers beneath the uppermost aquifer. The depth to groundwater in this zone is usually shallow and generally flows down the basin toward the Pajaro River. Recharge is from surface sources and from subsurface flows from the forebay.

Numerous individual aquifers occur in the lower aquifer zone. Groundwater in these aquifers is confined and generally flows down the valley to the southeast except where the regional gradient is interrupted by pumping troughs. Recharge is from subsurface flow from the forebay. From early historic times, wells tapping the southern portion of this zone, south of Old Gilroy, were flowing artesian wells. With greater amount of pumping in more recent times, the artesian pressures have declined and now only a few of the wells in the southernmost portion of the basin flow under pressure on a seasonal basis.

**Standards for the Construction and Destruction of Wells and Other Deep Excavations in Santa Clara County; Santa Clara Valley Water District; June 1989; pp. A11-A12

Within the Llagas Basin most of the waters are pumped from the forebay and lower aquifer zones, though many of the wells in the flat southern interior portion of the basin pump from both upper and lower aquifer zones. A cross sectional depiction of the Llagas Basin has been attached as Figure 2.

IV. PREVIOUS STUDY REVIEWS

As noted, this phase of the study consists of review of data which has been collected between 1956 and 1991 and analysis of trends in nitrate occurrence. Studies regarding nitrate occurrence in the Llagas Groundwater Basin have been previously conducted by consulting engineering firms, as well as state and regional public agencies. These studies included available information for over 600 water supply wells in the Llagas Basin, 492 of which were reviewed for this study. All sources of data with brief descriptions of each are listed below:

1. Brown and Caldwell—Geotechnical Consultants, Inc.: **County of Santa Clara: San Martin Area Water Quality Study—Phase 1 Report**, January 9, 1981. This report was prepared for the County of Santa Clara, and focused on general groundwater quality in the San Martin area of South Santa Clara County. Groundwater samples collected were analyzed for nitrates and other water quality parameters. Ten samples from ten wells were directly used in our review.

2. Luhdorff and Scalmanini—Consulting Engineers: **Ground-Water Monitoring Network and Program: Summary Report 1986**; Gilroy, California, August 1987. This report was prepared for the Gavilan Water Conservation District, and focused on the hydrogeology and general groundwater quality of the South County area. Groundwater samples collected were analyzed for nitrates and other water quality parameters. A total of 72 samples from 18 wells (4 sampling events) were used directly in our study.

3. Santa Clara County Health Department: **Santa Clara County Private Well Sampling Program—Final Report**, September 1988. This report was prepared by the County and included water quality results from sampling events during 1987 and 1988, from 1,225 wells throughout the County. Over 350 samples from different wells in the South County were directly used in our review.

4. Santa Clara Valley Water District: **Groundwater Quality 1980**, January 1980. This report was prepared by the District as a compilation of countywide water quality data. Over 170 sample results from over 40 wells from 1957 to the time of the report were directly used in our review.

5. Santa Clara Valley Water District, 1985 and 1991 Groundwater Sampling for General Groundwater Monitoring Program. The District performed periodic countywide groundwater sampling to assess groundwater quality. The groundwater samples were analyzed for nitrates and other water quality parameters. Ten of these wells were located in the South County, 6 of which were sampled in both 1984/85 and 1991.

6. State of California, The Resources Agency, Department of Water Resources, Central District: **South Santa Clara Valley Ground Water Quality Investigation: Memorandum Report**, June 1980. This report presented the results of groundwater sampling performed during 1978 and 1979 by DWR personnel. The samples were analyzed for nitrates and other water quality parameters. Results from over 80 wells were directly incorporated into our study.

7. State of California, The Resources Agency of California, Department of Water Resources: **Mineral Quality Criteria: South Santa Clara Valley—A Report to the Central Coastal Regional Water Pollution Control Board**, October 1963. This report was prepared by DWR for the Central Coast RWQCB to provide information on hydrogeology and general groundwater quality in South Santa Clara Valley. The report compiled historic water quality information. 30 samples from 20 wells were directly used in our report.

V. NITRATE CONCENTRATION TRENDS

PRESENTATION OF NITRATE TREND DATA

The trends which are referenced in this study are based on data from six selected wells which had a large number of analyses over a wide range of time. Nitrate concentrations found in the 492 wells used for this study ranged from approximately 25 mg/L to greater than 100 mg/L. The data was divided into ranges of concentrations in order to simplify presentation and to assess possible trends in nitrate concentration. Wells below 25 mg/L were not included as one of the categories in order to simplify presentation. It is important to note that 37 percent of the 571 wells sampled by the County Health Department in the South County area contained less than 25 mg/L nitrate. The data for the 492 wells with concentrations exceeding 25 mg/L was arbitrarily separated into four categories of nitrate concentration ranges as listed below, based on the highest concentration of nitrate historically observed in each well:

Category Designation	**Concentration Range**
A	25-45 mg/L
B	45-70 mg/L
C	70-100 mg/L
D	>100 mg/L

Wells were identified as shallow or deep based on whether they primarily represented zones less than or greater than 150 feet deep. This distinction is important because large municipal water supply wells generally draw from the deeper zones.

Table 1 summarizes the distribution of wells in each category by depth and status. The well status is also shown in Table 1 as active, inactive, or unknown. Active wells are those wells which have produced water within the past year. Wells classified as "inactive" have not produced water for a year or more and were tallied with wells which have been destroyed. A significant number of wells have an unknown or unrecorded status. This may be due to the changes in well numbers over the years or the lack of reporting of information to the District.

In order to assess possible trends, two example wells for each nitrate concentration category, totalling eight wells, were selected. Six of the eight wells were utilized in the trends analysis as two of the eight only had a few data points. These wells were considered useful because the large number of samples obtained reduced the relative error in assessing trends. The more points that are in the data set, the better the accuracy of correlation of nitrate concentration versus time. Wells with a large number of samples (greater than 13) collected over 15 or more years in each concentration range were selected as example wells. Previous nitrate data was unavailable for wells which were sampled in 1991, so these wells were not used as example wells. Due to these criteria, wells which were used as example wells were generally older wells for which construction details were unavailable.

The trends represented by the six example wells appear to be representative of those in most wells in the respective categories, based on review of the remaining wells. Despite the general lack of well construction information, this trend analysis is useful as an example of well water quality, as opposed to a specific aquifer quality, over time.

Table 2 indicates the location and status of the six example wells and table 3 tabulates the data from the eight example wells. Graphs were prepared to represent the trends in nitrate concentration in these example wells used in the trend analysis, and are shown in Figures 4 through 9. The graphs plot the collection date of the sample against the nitrate concentration detected. The graphs for each example well have been presented in a raw data format and a statistical format. The raw data format simply connects the data points between each time period. The straight line drawn through the field of data points is the statistical format based on a linear regression least-squares analysis. Least square linear regression is useful for scattergrams where the plotted data is scattered and trends are suspected but are difficult to notice. The trend analysis for each of the categories is included as Figures 4 through 9 and the raw data graphs for each of the categories are included as Figures 4a through 9a. There was not enough data to establish a statistical trend for both wells in Categories C and D.

FINDINGS

There are eight findings regarding nitrate occurrence and changes in concentration in Llagas Basin. These findings are listed and described below:

1. A gradual increase of nitrate concentrations is apparent, based on the historical data collected from the six wells. Additionally, the majority of other wells which were sampled several times over a period of 15 or more years displayed a gradual increase in nitrate concentration similar to the six example wells.

2. In Category A (25-45 ppm) example wells, the nitrate concentration trend appears to be increasing, based on a least-squared regression analysis of the data points. The minimum nitrate concentration detected in well 10S3E26J1 was 21 ppm in 1959; the maximum was 40.5 ppm in 1975. The minimum nitrate concentration detected in well 10S4E18J1 was 8.5 ppm in 1959; the maximum was 44.9 ppm in 1975. Between the time span of 1958 and 1977, the data shows a general increasing trend; on a smaller time scale, fluctuations in nitrate concentrations can be noted. Please refer to Figures 4 and 5.

3. In Category B (45-70 ppm) example wells, the nitrate concentration trend also appears to be increasing. The minimum nitrate concentration detected in well 10S3E01E2 was 6.7 ppm in 1957; the maximum was 50 ppm in 1965. The minimum nitrate concentration detected in well 11S4E21B2 was 28 ppm in 1958; the maximum was 65.1 ppm in 1976. Fluctuations in nitrate concentration are noticeable within short time spans, but the overall trend, as evidenced on Figures 6 and 7, appears to be increasing.

4. The Category C (70-100 ppm) example well (Well No. 10S4E34L05) had an increasing trend of nitrate concentration. Only one well was used for trend analysis because none of the other wells in this category had a sufficient number of samples. This is shown in Figure 8. The minimum nitrate concentration detected in well 10S4E34L5 was 32 ppm in 1964; the maximum was 92 ppm in 1978. The other well in this category (11S4E04Q3) indicated a minimum nitrate concentration of 29 ppm in 1975 and a maximum nitrate concentration of 77 ppm in 1960.

5. The Category D (> 100 ppm) example well (Well No. 11S4E04Q03) had a slightly increasing trend. The data was more scattered in this set and the 1962 data point of 3.8 ppm was not used in the trend analysis. This data point is more than 10 times less than the lowest value in the data set and almost 30 times less than the highest value. For these reasons, the validity of this point is questionable. Other than that data point, the minimum nitrate concentration recorded was 40

ppm in 1963 and 106 ppm in 1976. Please refer to Figure 9. The minimum concentration detected in the other well (Well No. 11S4E03N02) in this category was 75 ppm in 1960 and 130 ppm in 1987. This well was not included in the trend analysis because there were only two data points and was too small a data set for analysis.

6. Wells from different areas of the basin seem to equally reflect the increasing trends. However, a small percentage of the wells (5 to 10 percent) showed wide fluctuations in nitrate concentrations.

7. Wells which initially exhibited significant nitrate concentrations rarely produced groundwater samples with nondetectable or very low nitrate concentrations thereafter.

8. Fluctuations in nitrate concentrations on an annual basis were very small during more frequent sample collection program for 17 wells performed in various years. Yet, three of the wells contained wide fluctuations of nitrates during the year. However, for all 17 wells there were wide fluctuations in nitrate concentrations over several years of infrequent sample collection. The wells were sampled various years between two and six times during 1 year.

NITRATE CONCENTRATIONS VERSUS GROUNDWATER ELEVATION

A correlation between hydrologic data and nitrate concentration was initially considered, based on the theory that percolation and an increase in groundwater levels would result in desorption of nitrates from the unsaturated zone into the groundwater. Because groundwater elevations did not consistently vary in response to varying rainfall, rainfall data appeared independent of groundwater elevations, apparently due to well pumping and subsequent fluctuations in the groundwater table. Historic rainfall data for Santa Clara County has been attached as Table 4. The rainfall data was collected at the San Jose gauging station and is included to give a general idea of the magnitude of precipitation received that year. Rainfall data from the Peabody Ranch gauging station, which is closer to the study area, will be evaluated for future reports.

Maintaining the premise that groundwater fluctuations may result in sorption and desorption of nitrates, a review of groundwater elevation data versus nitrate concentration was undertaken. Twelve wells from which groundwater samples and groundwater elevation measurements were collected on or about the same day were selected for analysis. Comparisons of nitrate concentrations to groundwater elevation were made for each well between sampling and surveying events. It appears that a conclusive correlation was not possible at the specific well location, as nitrate concentrations did not consistently vary with changing groundwater elevation. Please refer to Table 5 for a tabulation of this data.

On a more regional level, however, an increase in nitrate concentrations displayed in three of the four wells correlated with a decrease in groundwater elevation. The three wells are located in the confined area of the Llagas Basin, which supports the possibility of an increased/decreased potentiometric head (which would only be measured in the well), rather than a rise in the water table surface, where desorption probably would occur. Also, five of the six wells which indicated decreased nitrate concentrations with a decrease in water level were located north of the confined region in an unconfined area, possibly indicating a water table drop below a nitrate loaded shallow soil zone. Please note that this discussion is limited to 12 wells. This data is included in Table 6.

PRESENTATION OF NITRATE SPATIAL DISTRIBUTION DATA

The spatial distribution is based on 143 of the 492 wells in the study; the 1988 Santa Clara County Health Department study was not utilized for generation of the areal distribution maps in order to plot and identify specific wells without losing clarity of well locations due to excessive well location clutter.

Nitrate concentration maps, based on the data collected from past studies, were prepared to show areal distribution. Four separate maps were prepared to represent categories of nitrate concentrations as outlined above and are included as Figures 10 through 13. Each well is plotted on only 1 of the 4 maps in Figures 10 through 13. The map on which they are plotted correlates to the highest concentration of nitrate historically observed in the well. The concentrations of 25-45 ppm, 45-70 ppm, 70-100 ppm, and > 100 ppm are indicated on the maps as categories A, B, C, and D, respectively.

Available data included data from samples collected in different areas of the basin over various years. The agreement between the SWRCB and the District stipulates that this report include "a map of the area showing isopleths of groundwater nitrate concentration." We were unable to draw these isopleths for the following three reasons:

1. Well construction details were unavailable for most of the wells from which samples have been collected. Thus, it is not possible to determine the vertical distribution of nitrate occurrence from historical data. As a result, two-dimensional isopleths may misrepresent actual three-dimensional subsurface conditions.

2. Samples were collected from different areas of the basin at different times. Creating isopleths based on historical nitrate concentrations may not be a realistic geographic representation of nitrate distribution for a given time period.

3. Nitrates found in Llagas Basin groundwater may have various point and nonpoint sources. The assumptions inherent in constructing isopleths may misrepresent the actual conditions, with respect to the nitrate concentrations in groundwater present between wells from which data has been collected. Nitrate distribution in Llagas basin groundwater would need to be displayed in three dimensions to be accurate, especially given the highly stratified nature of the basin's subsurface.

As noted in Figures 10 and 11, the distribution of nitrate concentrations in categories A and B appears random and scattered throughout the basin. As concentrations increase to over 70 ppm (Categories C and D), however, the distribution of wells appears to be more focused in the area of the confining layer in the southern portion of the basin. This is noted in Figures 12 and 13. Acknowledging the uncertainty of well screen location and depth, the samples, nonetheless, represent nitrate concentrations in the well water.

The cluster of wells containing high nitrate concentrations may be attributed to three general scenarios. It is possible that nitrates have migrated from distant sources and accumulated under the confining layer; however, this is only speculative due to the lack of well screen data. The other scenario is that elevated nitrates have migrated vertically from a local source, through the well itself or a nearby conduit. Finally, a combination of the first two scenarios would indicate the possibility of both vertical migration from a shallow to a deep aquifer via the well and horizontal migration from a distant source.

VI. INTERPRETATIONS

This portion of the comprehensive nitrate study was intended to be an evaluation of previous data from studies conducted in the Llagas Basin regarding nitrate distribution in groundwater. The data collected for this study was previously generated via seven studies spanning the last 35 years, included a basin-wide county study. Data from a total of 492 wells were directly evaluated for this report.

One of the primary uncertainties involved in compiling data from studies which have been conducted over a long period of time and by various entities is sample collection procedure. The amount of well development, sample collection protocol, sample storage, and sample transport may affect the accuracy of the sample. Also, the uncertainty of the wellscreen location makes it difficult to assess nitrate concentrations in a specific aquifer. The general lack of well construction data for wells included in this study provides a significant restriction in drawing definitive conclusions regarding vertical nitrate distribution in the Llagas Basin. Given these limitations, however, the following assessment of the data is possible:

1. There appears to be a general trend of increasing nitrate concentrations in selected example wells in the Llagas Basin during the period from 1957 to 1978. The trends in Figures 4 through 9 indicate an increase in nitrate concentrations in the well water sampled.

2. Older wells without well construction information in the study area are most likely screened in all possible water-bearing zones, for maximum water yield. The lack of well construction detail makes it difficult to assess nitrate occurrence in a specific aquifer. Also, due to dilution, wells which have produced groundwater samples which exceed the nitrate MCL of 45 ppm can be assumed to intersect one or more aquifers which have nitrate concentrations greater than 45 ppm.

3. Samples collected from the well are representative of the well water regardless of the screened interval of the wells. Therefore, trends are independent of screened interval and represent the nitrate concentration of the well water at that time. Thus, any trend would be one of the well water and not a particular aquifer.

4. Fluctuations in the groundwater table may also affect nitrate concentrations. However, it is difficult, at this time, to ascertain these groundwater fluctuation effects.

5. The areal distribution of nitrates in the well water was also considered using 143 of the 492 wells reviewed for this study. Nitrate concentrations in excess of drinking water standards have been detected in wells in all areas of the basin. The concentration of nitrate in the Category C and Category D wells in the southern portion of the basin could be due to three scenarios:

    a. Assuming that the wells are screened in the lower unit, nitrates may have migrated from a distance along with groundwater flow toward the southern portion of the basin and accumulated in the lower unit; or

    b. Assuming that the wells are screened in the upper unit, nitrates may have migrated locally from the surface into the upper unit; or

    c. Assuming that the wells span both upper and lower aquifers, nitrate occurrence may be due to both distant migration in the lower aquifer and local migration from surface sources.

Having established trends in nitrate distribution in the Llagas Basin, the next step is to assess possible sources of nitrates. During the next study phase, land uses will be evaluated and possible source areas identified. The evaluation results will be used, in part, for the subsequent phase to select sample collection locations.

TABLE 1
Summary of Wells in Each Nitrate Concentration Category

Nitrate Concentration Category[1]	No. of Wells	% of Total	Well Status			Well Depth[2]		
			Active[4]	Destroyed or Inactive	Unknown or Unrecorded[3]	Known		Unknown or Unrecorded
						<150′	>150′	
25-45 mg\L	**214**	**43**	153	6	55	13	56	145
45-70 mg\L	**178**	**36**	122	5	51	14	50	114
70-100 mg\L	**77**	**16**	62	2	13	5	18	54
>100 mg\L	**23**	**5**	16	0	7	3	3	17
TOTAL	**492**	**100**	353	13	126	35	127	330

Notes:

[1] Based on highest historical concentration recorded.
[2] Perforated intervals and lithologic information unavailable for most wells.
[3] Based on information available to the District, it is uncertain whether this category of wells is currently in use.
[4] An active well is one which has produced water over the past year.

TABLE 2
Nitrate Concentration Trend Evaluation Example Wells

Example Well Category[1]	Well No.	Well Status	Well Depth
25-45 mg/L	10S3E26J1	Unavailable[2]	Unavailable
25-45 mg/L	10S4E18J1	Current	180 feet
45-70 mg/L	10S3E01E2	Current	250 feet
45-70 mg/L	11S4E21B2	Unavailable	Unavailable
70-100 mg/L	10S4E34L5	Current	Unavailable
>100 mg/L	11S4E04Q3	Unavailable	Unavailable

Notes:

[1] Example well categories selected to provide for even distribution of the data among the 4 maps. The only number of water quality significance is 45 mg/L, the MCL for nitrate.
[2] Same as (2) in table above.

TABLE 3
NITRATE CONCENTRATIONS FOR EXAMPLE CATEGORY WELLS USED IN TREND ANALYSIS

Year	Category 25-45 mg/L		Category 45-70 mg/L		Category 70-100 mg/L		Category >100 mg/L	
	Well ID No. 10S3E26J1	Well ID No. 10S4E18J1	Well ID No. 10S3E01E2	Well ID No. 11S4E21B2	Well ID No. 10S4E34L5	Well ID No. 11S4E08K2	Well ID No. 11S4E04Q3	Well ID No. 11S4E03N2
1957			6.7					
1958	23.0	13.0	19.0	28.0	32.0		59.0	
1959	21.0	15.0	19.0	35.0	32.0		84.0	
1960	22.0	13.0	22.0	35.0	33.0	77.0	70.0	75.0
1961	26.0	17.0	42.0	45.0			75.0	
1962	23.0	10.0	24.0	37.0	43.0		3.8[*]	
1963	26.0		13.0	38.0	35.0		40.0	
1964		8.5	11.0		32.0		84.0	
1965			50.0				65.0	
1966	23.0		26.0	47.0	34.0		85.0	
1967	28.0		33.0	48.0			88.0	
1968		16.0	34.0	48.0	56.0			
1969								
1970								
1971	23.0	17.0	34.0	52.0	52.0	73.0	104.0	
1972				62.0	62.0	58.0	85.0	
1973	36.0	28.0		57.0	43.0	76.0	82.0	
1974				41.4	73.0	58.8		
1975	40.5	32.8	38.3[1]	40.9	48.0	29.0	70.0	
1976	33.9	42.0	44.0	65.1	57.0	68.6	106.0[2]	
1977	19.8	44.9	38.3	46.6	62.0	76.6	71.0	
1978		40.0	27.4	48.0	92.0			
1979				39.0				
1980								
1981								
1982								
1983								

TABLE 3
NITRATE CONCENTRATIONS FOR EXAMPLE CATEGORY WELLS USED IN TREND ANALYSIS (continued)

Year	Category 25-45 mg/L		Category 45-70 mg/L		Category 70-100 mg/L		Category >100 mg/L	
	Well ID No. 10S3E26J1	Well ID No. 10S4E18J1	Well ID No. 10S3E01E2	Well ID No. 11S4E21B2	Well ID No. 10S4E34L5	Well ID No. 11S4E08K2	Well ID No. 11S4E04Q3	Well ID No. 11S4E03N2
1984								
1985			46.0					
1986								
1987								130.0
1988								

Notes: *Point not used in trend analysis.

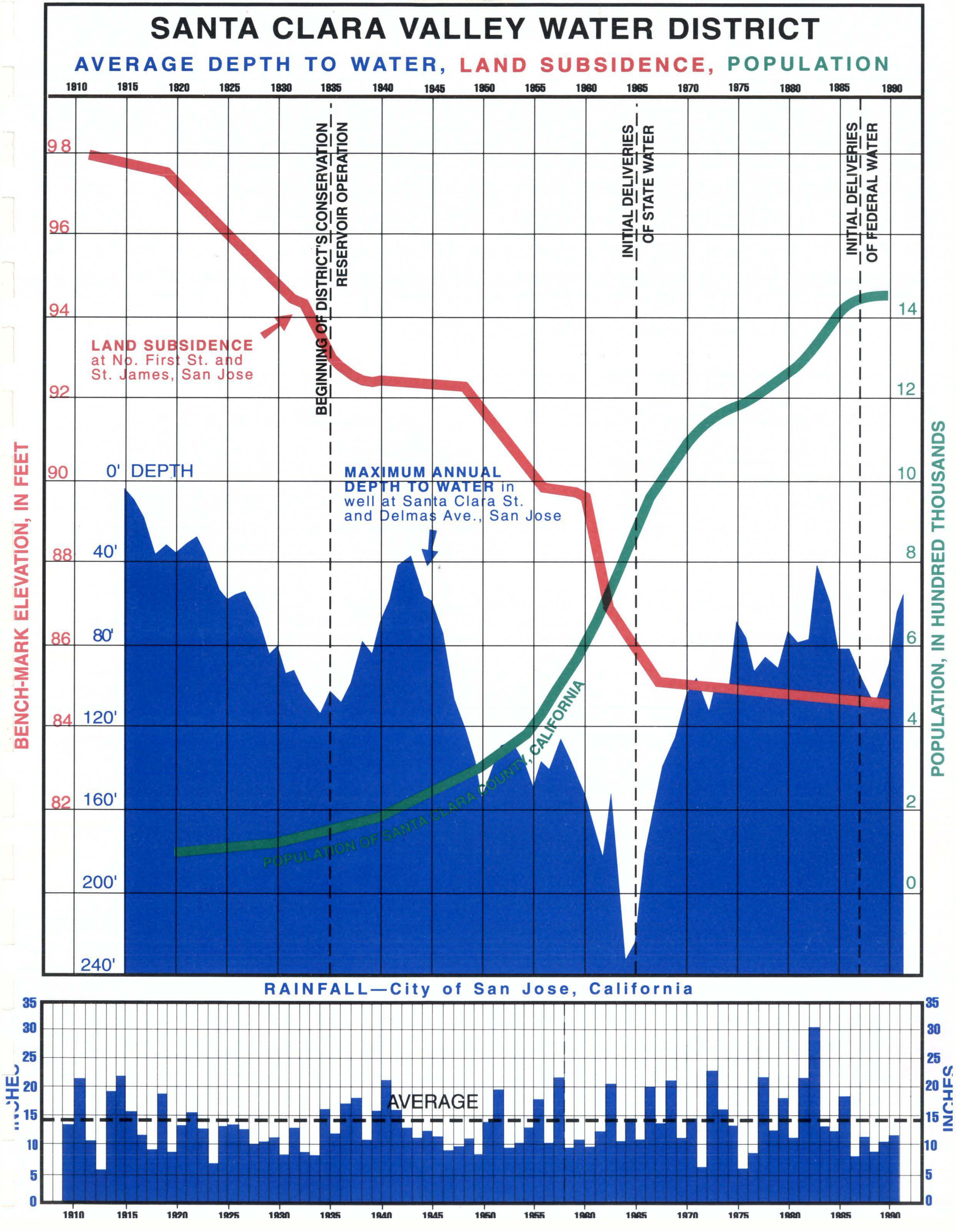
Wells K2 and N2 not utilized for graphing due to the large time gap and small number of data points.

[1] Also 46.5 mg/L sample collected later in the year.

[2] Also 67 mg/L sample collected later in the year.

[3] Depth to water for the above example wells was unavailable at the same time of sampling. The wells were selected for a high number of nitrate sampling events.

TABLE 4



SANTA CLARA VALLEY WATER DISTRICT

AVERAGE DEPTH TO WATER, LAND SUBSIDENCE, POPULATION

RAINFALL—City of San Jose, California

TABLE 5
NITRATE CONCENTRATION VS. DEPTH TO WATER IN SELECTED WELLS
(All Concentrations in mg/L as Nitrate and Depths in Feet)[1]

Well No.	Nitrate Concentration (Date Sampled only)	Depth to Water	Date Sampled and Gauged (Date Sampled only)
9S3E33M03	22.6	12.1	10/28/75
	25.5	49.5	08/23/77
9S3E36F01	22.0	104.0	08/12/63
	17.0	113.8	07/27/64
10S3E01E2[2]	47.0	51.0	10/28/75
	44.0	71.0	08/12/76
	38.0	94.0	08/24/76
10S3E13D03	19.0	54.1	08/21/73
	(06/15/93) 20.5	103.3	(06/30/77)
10S3E14D01	33.0	64.3	08/07/73
	22.0	64.3	08/13/75
	27.7	112.2	07/20/76
	30.4	107.0	08/23/77
10S3E26J1[2]	40.5	9.2	08/13/75
	34.0	19.4	08/19/76
	20.0	23.0	07/19/77
10S4E18G02	35.0	58.7	10/21/75
	37.8	98.1	07/06/76
	20.7	117.5	07/19/77
10S4E18J01[2]	32.8	68.9	10/21/75
	44.9	131.9	08/24/77
10S4E31G04	(09/26/72) 15.0	84.0	(09/29/72)
	(12/11/74) 48.4	38.1	(12/01/74)
	44.0	56.1	08/14/75
	(08/24/76) 47.0	89.9	(08/27/76)
	(07/19/77) 46.6	107.9	(07/22/77)
10S4E34L05[2]	48.0	78.7	07/17/75
	57.0	110.9	07/20/76
	62.0	100.7	05/26/77
11S4E06B01	(06/08/91) 18.0	42.0	(05/31/71)
	(12/11/74) 28.6	40.0	(12/01/74)
	(08/14/75) 17.6	58.1	(08/01/75)
	(06/29/76) 25.5	79.1	(06/25/76)
11S4E16J01	27.0	—	—
	(06/16/71) 53.0	14.1	(06/08/71)
	(08/08/72) 4.6	11.2	(08/15/72)
	(08/14/75) 22.0	8.9	(09/11/75)

Note: [1]Twelve of the above data pairs were not collected on the same day; however, less than 2 weeks separates the dates in each case. Dates in parentheses indicate different sampling and gauging dates.
[2]This well was also used in trend analysis graphical representation.

TABLE 6
NITRATE DATA AND WATER TABLE EVALUATION[1]

WELLS WITH DECREASING CONCENTRATIONS	
Declining Water Level	
Well Number	**Confined (C) or Unconfined (U)[2]**
9S3E33M03	U
9S3E36F01	U
10S3E01E02	U
10S3E26J01	U
10S4E18G02	U
Increasing Water Level	
Well Number	**Confined (C) or Unconfined (U)**
11S4E16J01	C
WELLS WITH INCREASING CONCENTRATIONS	
Declining Water Level	
Well Number	**Confined (C) or Unconfined (U)**
10S4E18J01	C
10S4E34L05 (one of two time spans)	C
11S4E06B01** (one of three time spans)	C
Increasing Water Level	
Well Number	**Confined (C) or Unconfined (U)**
10S4E31G04* (two of three time spans)	U
11S4E06B01** (two of three time spans)	C
WELLS WITH RELATIVELY STABLE CONCENTRATIONS	
Declining Water Level	
Well Number	**Confined (C) or Unconfined (U)**
10S3E14D01	U
10S4E31G04*	U
10S3E13D03	U

Notes: [1] This table is based on select wells based on coincident sampling and water level gauging dates. The data is based on a limited number of years of depth to water measurements due to the sparse number of coincident sampling/gauging events.

[2] The reference to confined or unconfined.

* Well number 10S4E31G04 showed an increase in nitrate concentration with an increase in water level and also indicated relatively stable concentrations with a decline in water level.

** Well number 11S4E06B01 showed an increase in nitrate concentrations with an increase and decrease in water levels.

NOTES ON FIGURES 10-13: WELL WATER NITRATE CONCENTRATION MAPS

The base map with valley floor boundaries and confined zone boundary was obtained from the Santa Clara Valley Water District map entitled "Groundwater Level Monitoring Wells—Santa Clara Valley, South County," June 1992.

Well water concentrations represent the single highest nitrate concentration detected in that well, based on data compiled between 1958 to 1991 from the seven studies noted in the text of the report (total of 143 wells plotted).

The boundary of the confined area is approximate and does not indicate that all areas inside the zone are ideally confined.

Screened zones of wells are typically unknown. Therefore, nitrate concentrations represent water in well only and not a specific aquifer.

Well locations are approximate and were obtained from Santa Clara Valley Water District Well Section plots on United States Geological Survey 7.5 minute quadrangle maps (1:1000 scale). The maps used were: Morgan Hill, Mt. Sizer, Mt. Madonna, Gilroy, Gilroy Hot Springs, Chittenden, and San Felipe.

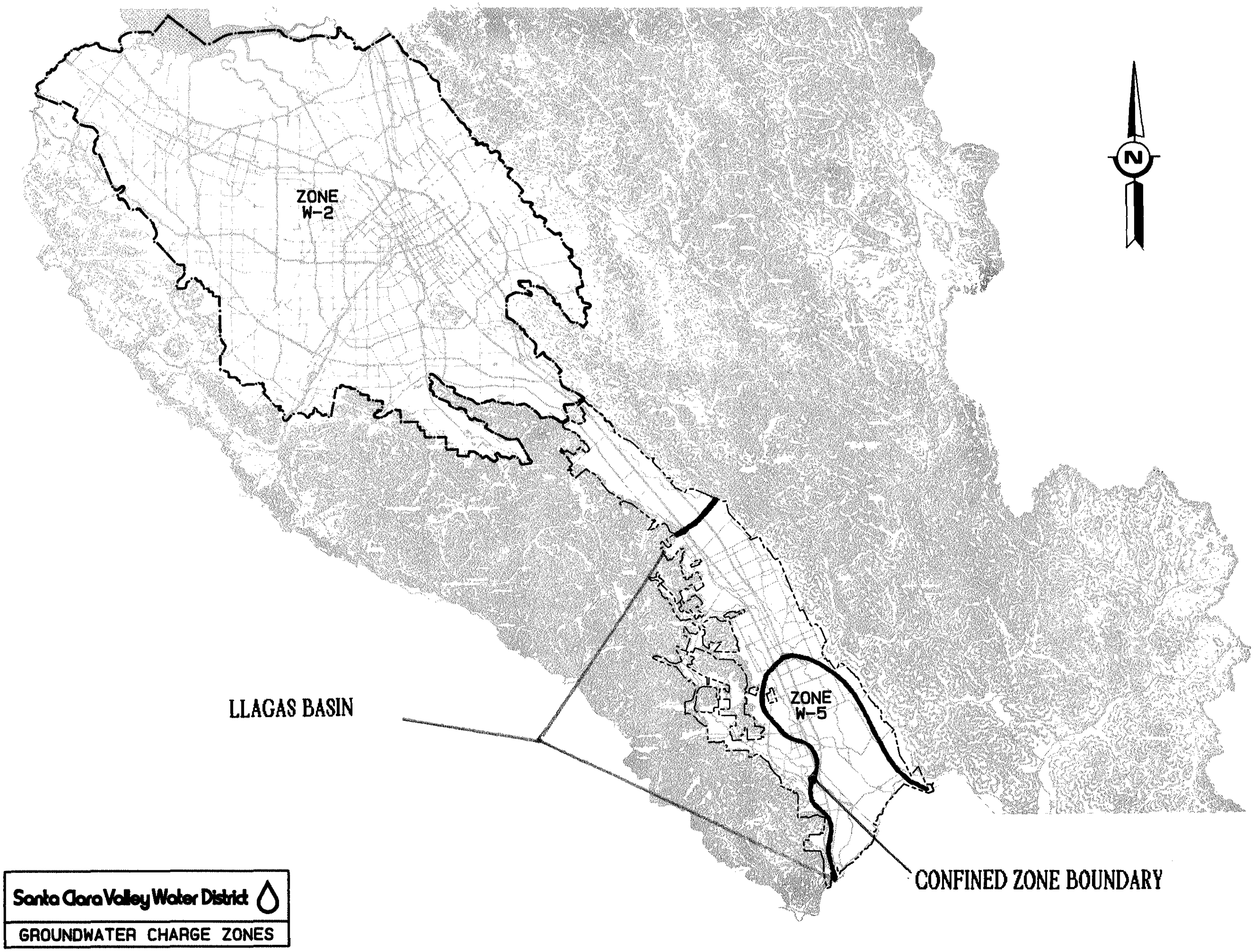
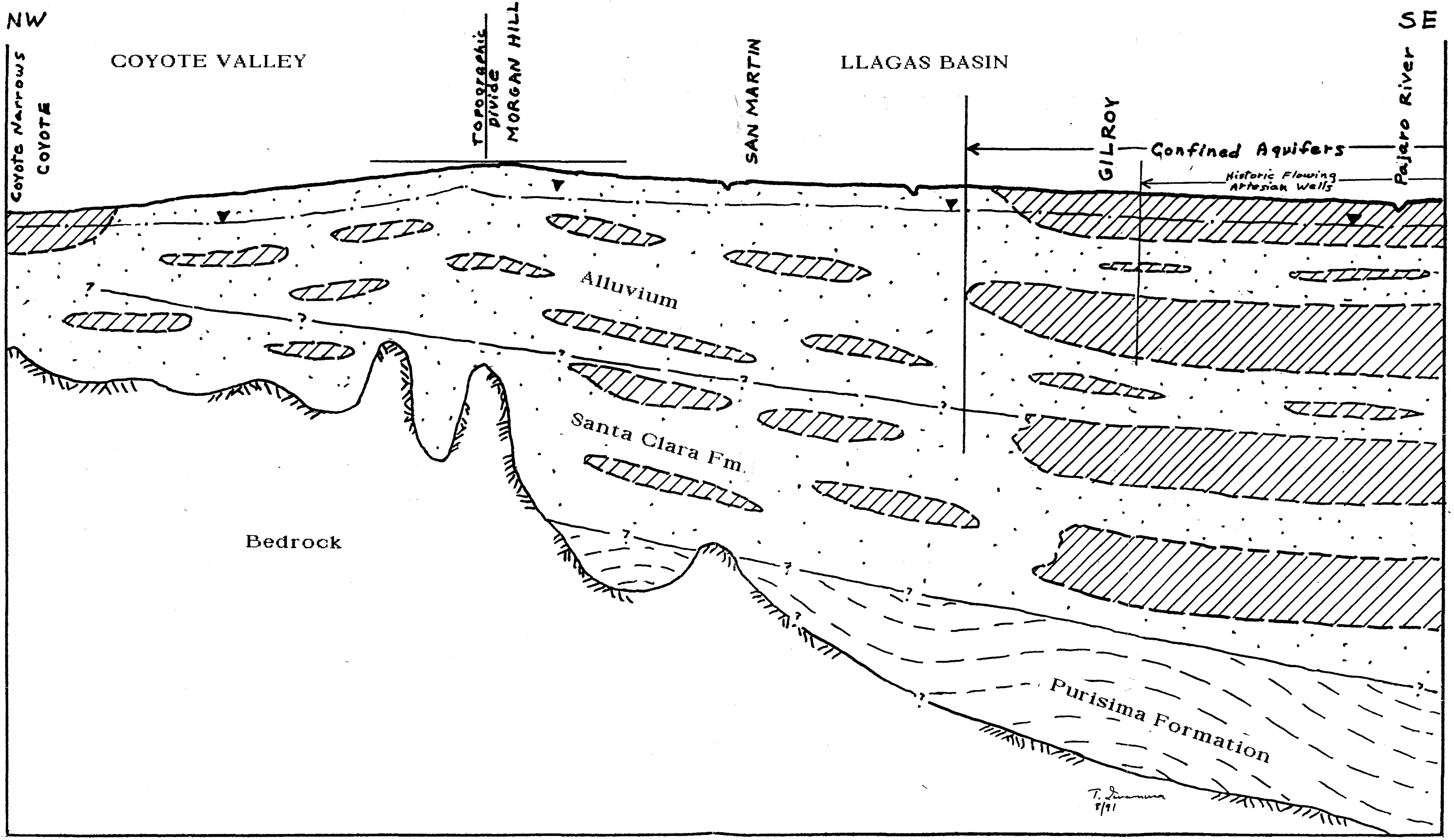


FIGURE 1: SANTA CLARA VALLEY AND LLAGAS BASIN



Not to scale

FIGURE 2: DIAGRAMMATIC CROSS SECTION
COYOTE VALLEY - LLAGAS BASIN

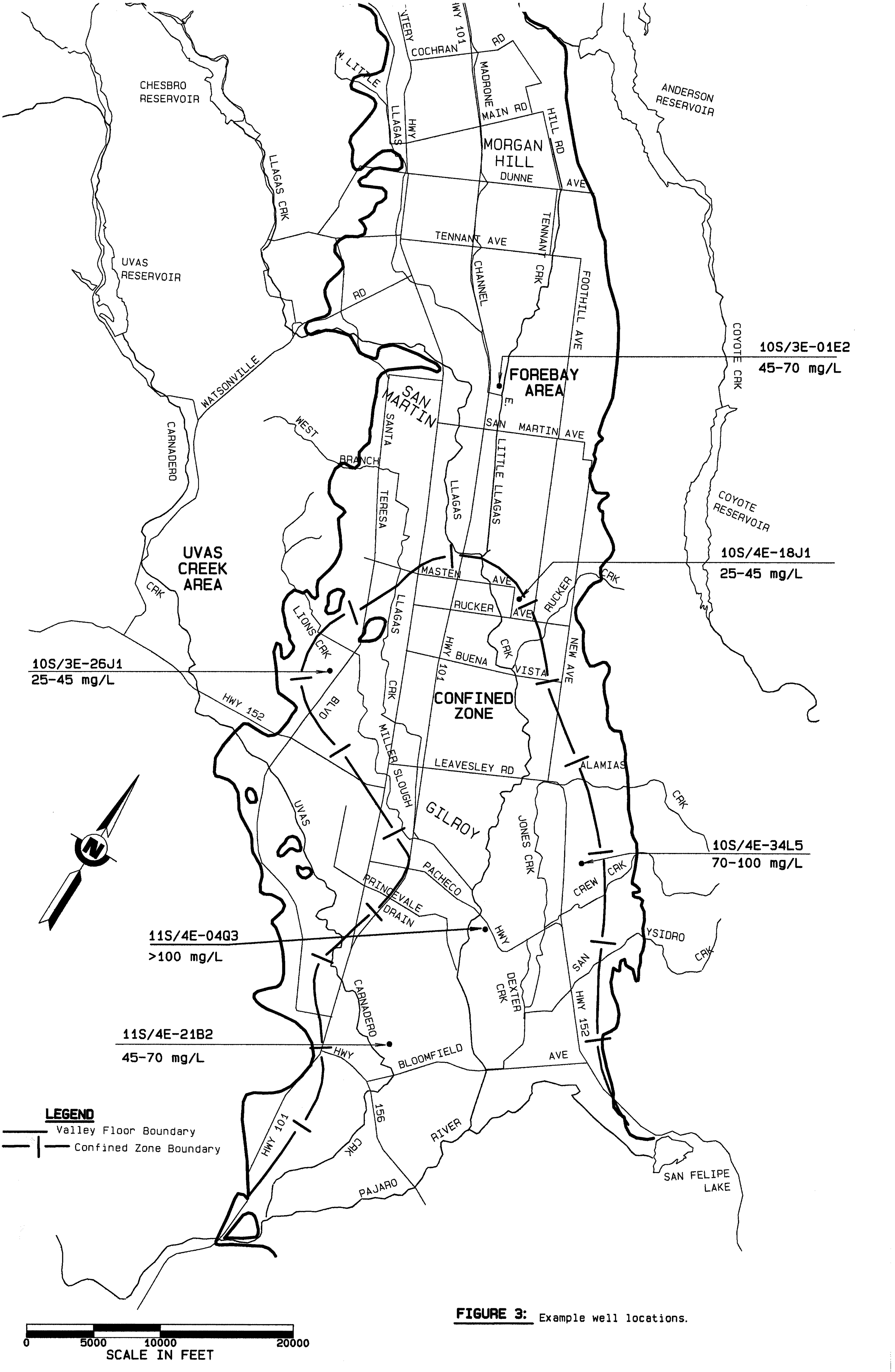


FIGURE 3: Example well locations.

Nitrate Trends in Well #10S3E26J1

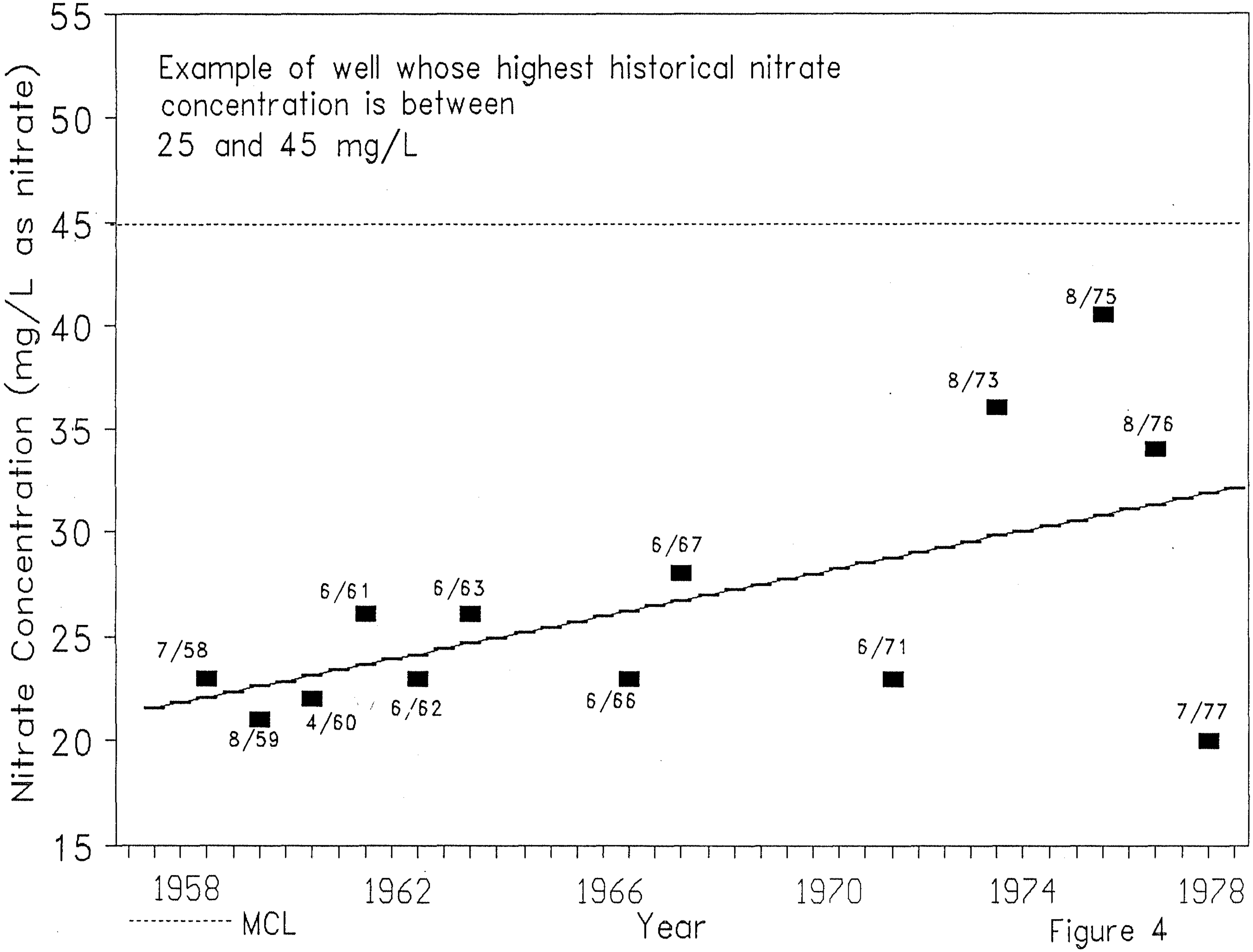


Figure 4

Nitrate Trends in Well #10S3E26J1

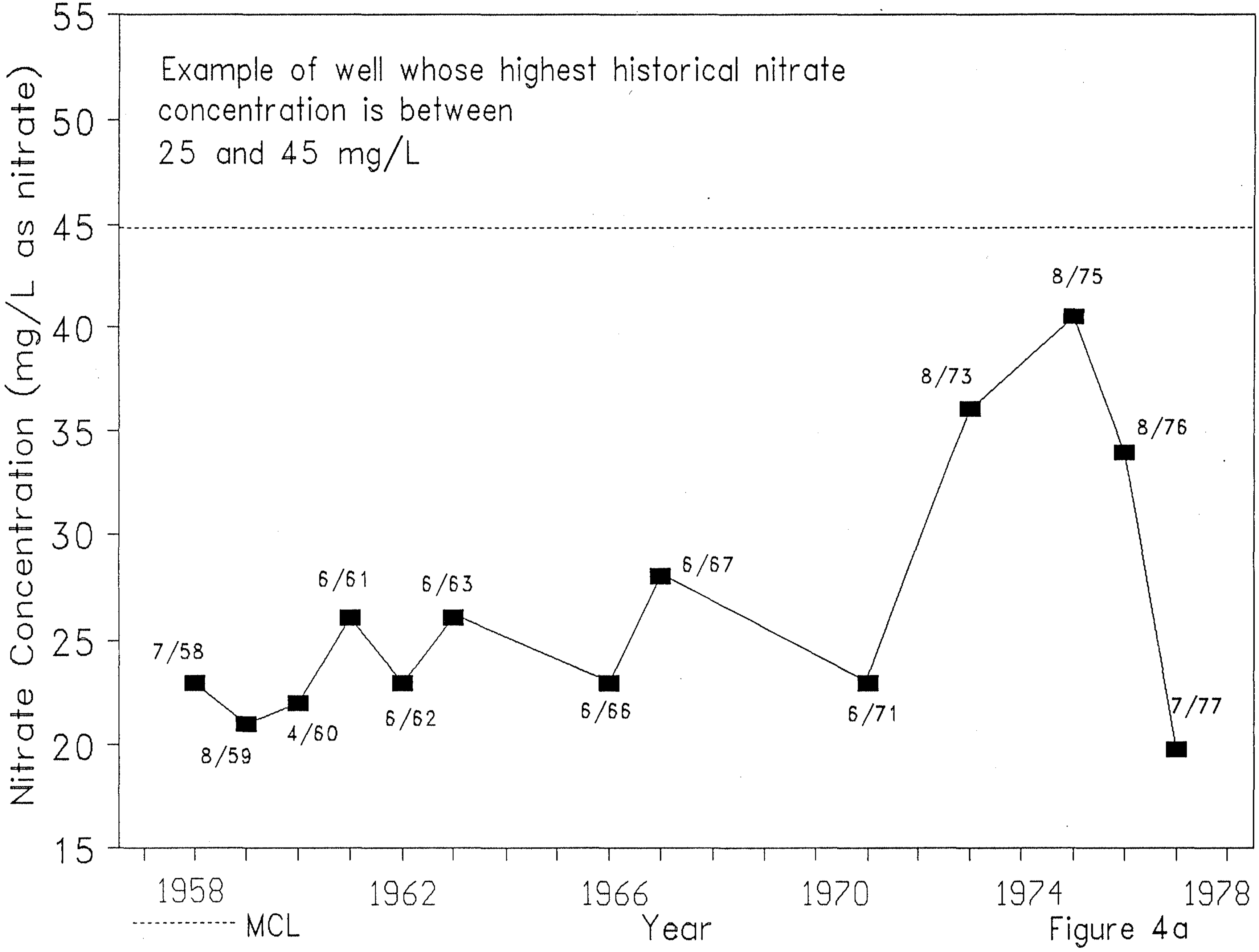


Figure 4a

Nitrate Trends in Well #10S4E18J1

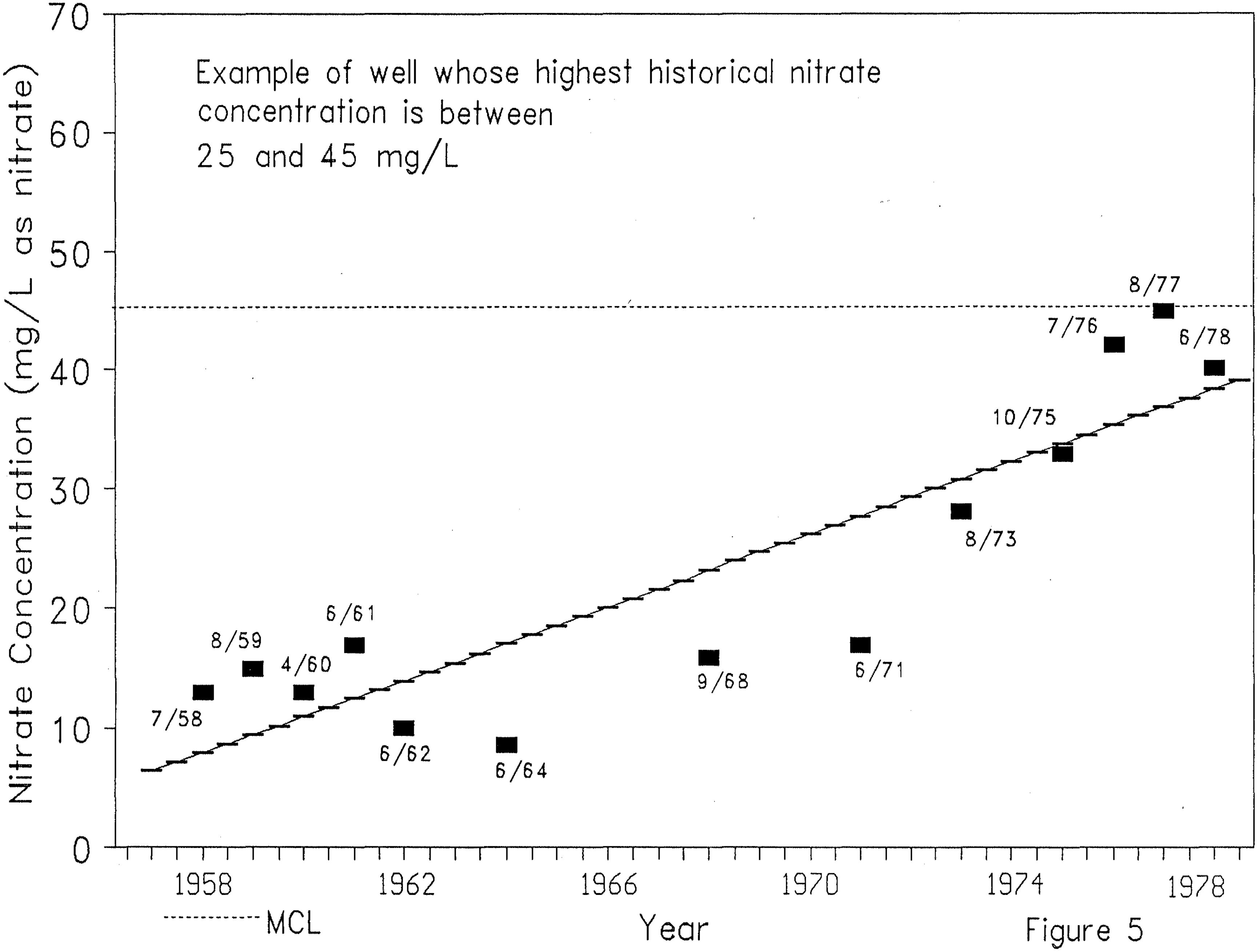


Figure 5

Nitrate Trends in Well #10S4E18J1

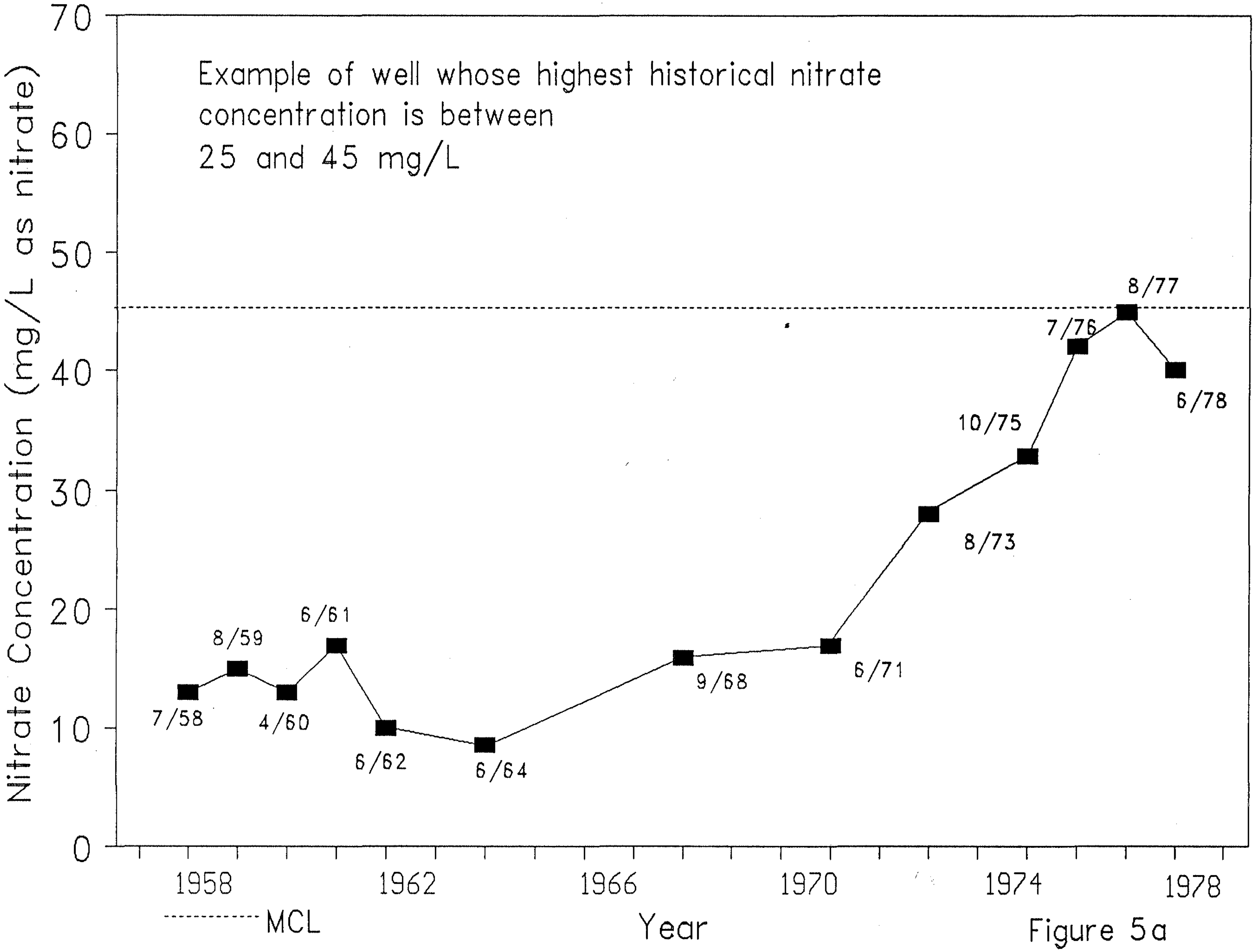


Figure 5a

Nitrate Trends in Well #10S3E01E2

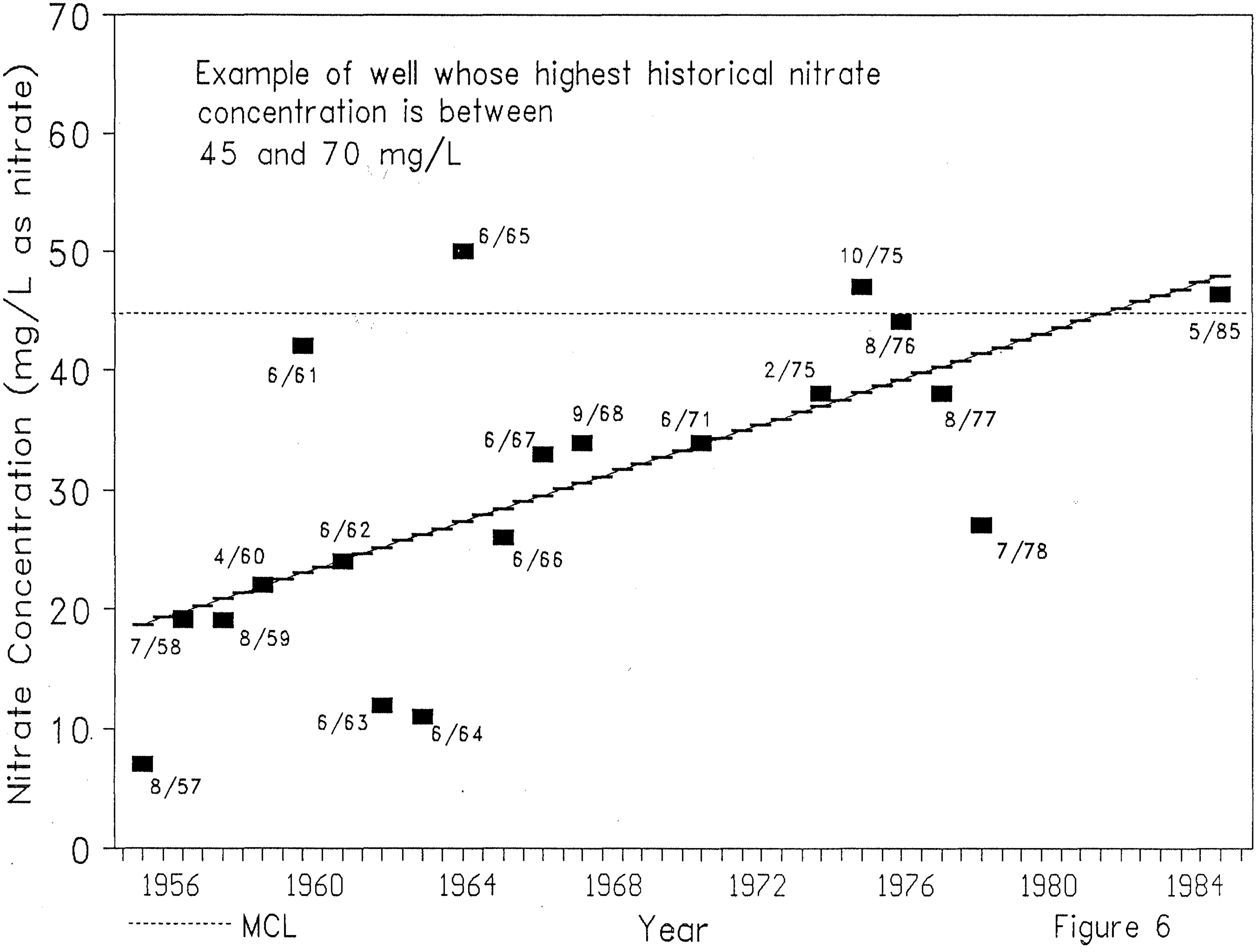


Figure 6

Nitrate Trends in Well #10S3E01E2

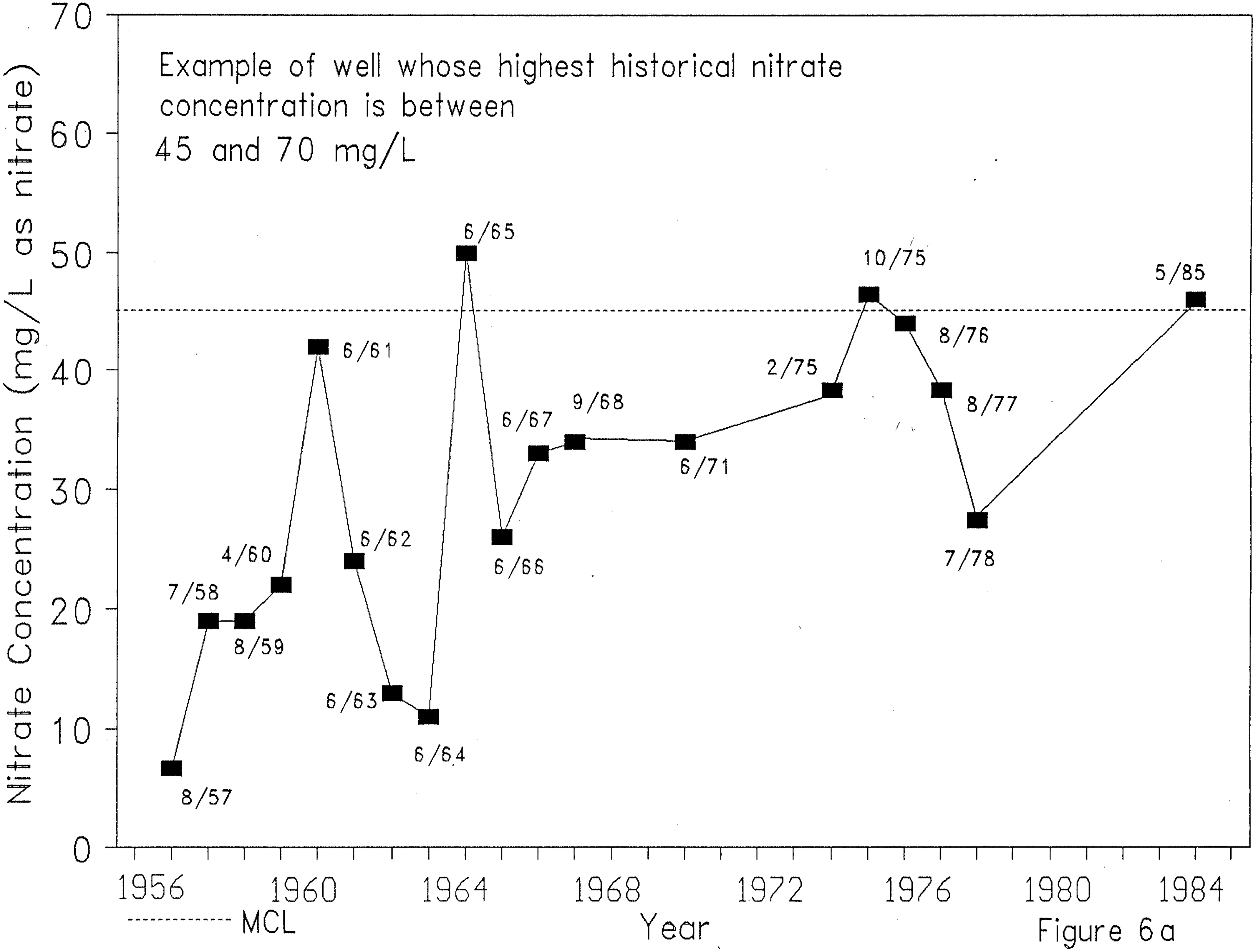

Example of well whose highest historical nitrate concentration is between 45 and 70 mg/L

Figure 6a

Nitrate Trends in Well #11S4E21B2

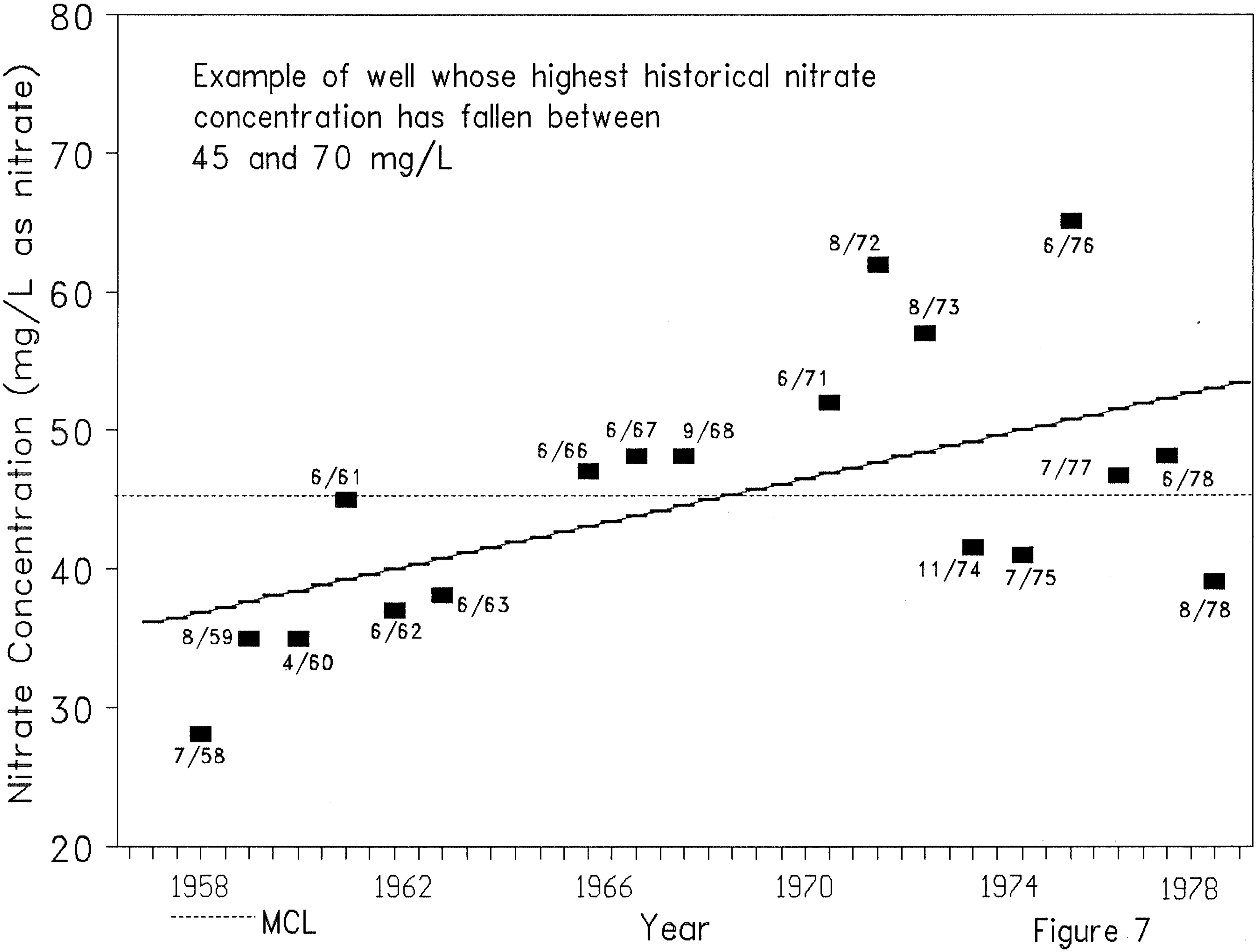


Figure 7

Nitrate Trends in Well #11S4E21B2

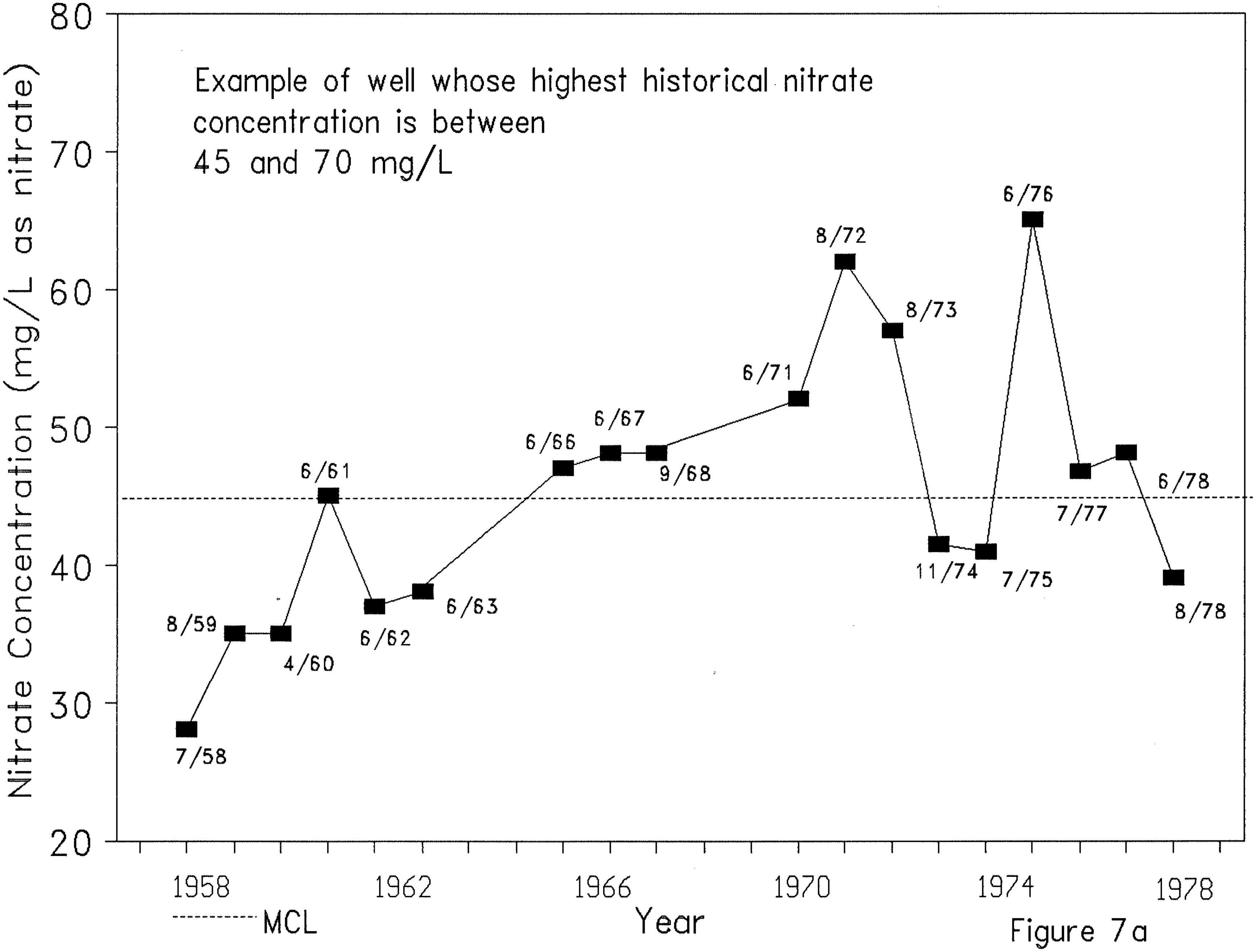


Figure 7a

Nitrate Trends in Well #10S4E34L5

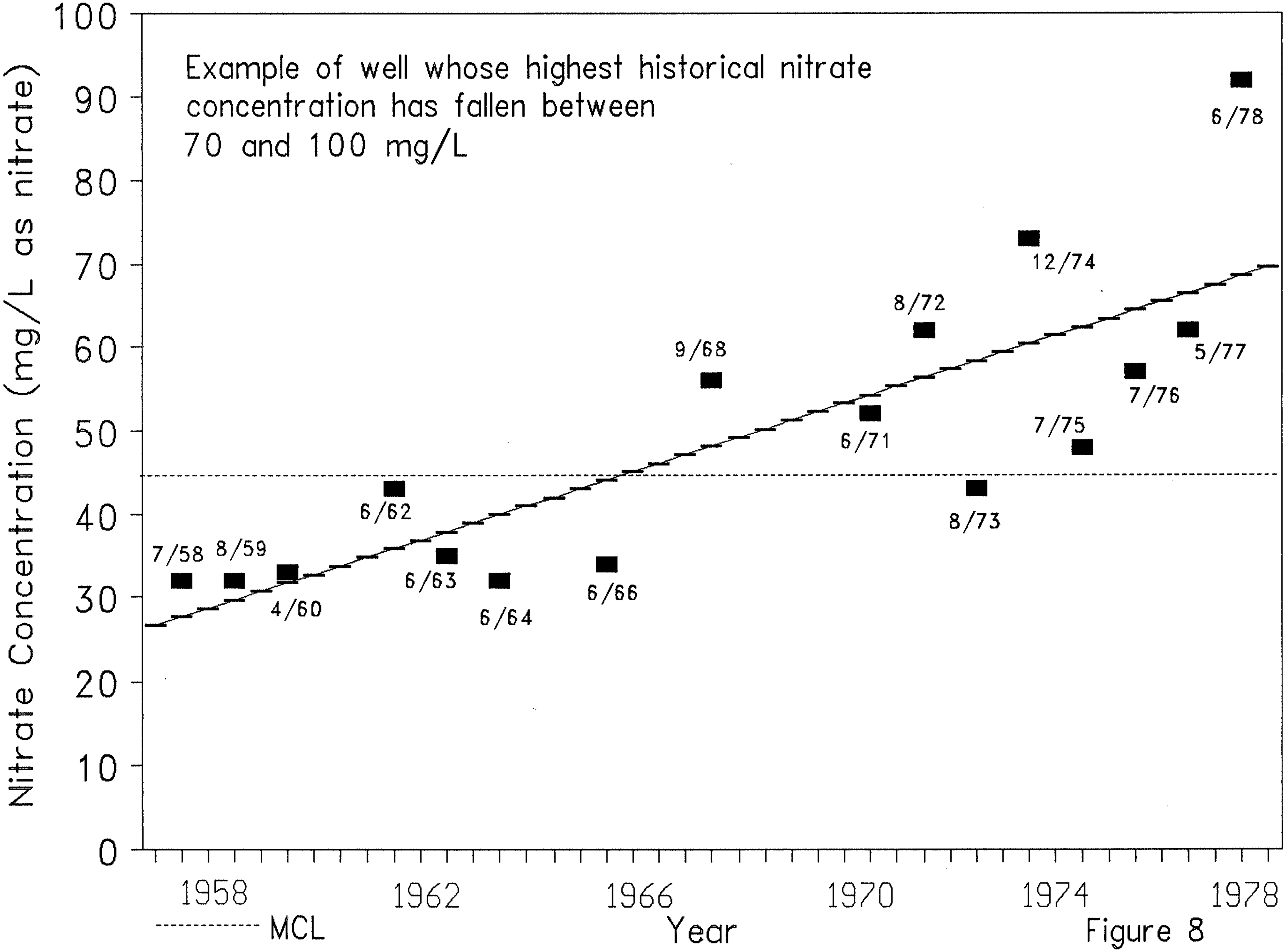


Figure 8

Nitrate Trends in Well #10S4E34L5

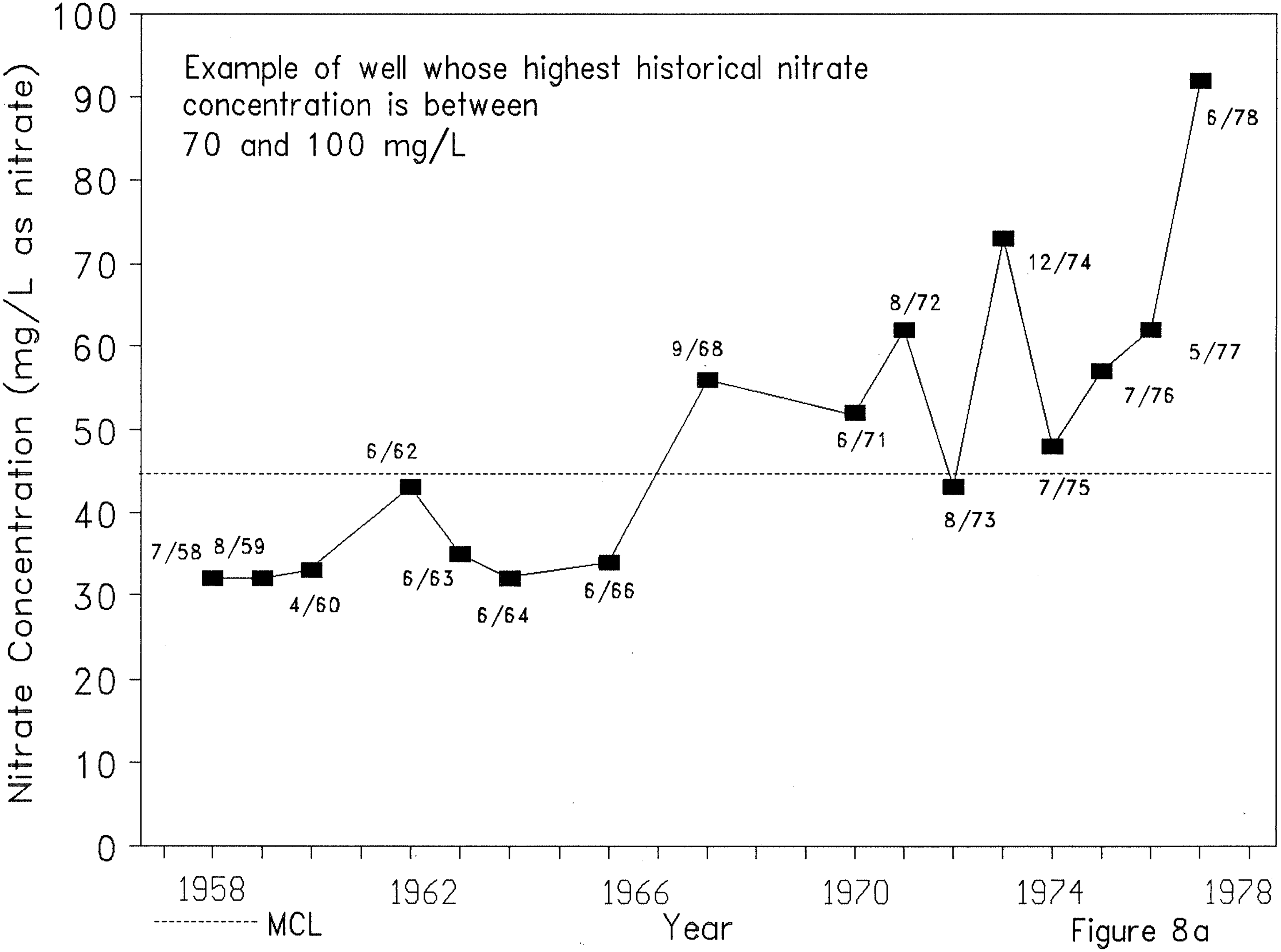


Figure 8a

Nitrate Trends in Well #11S4E04Q3

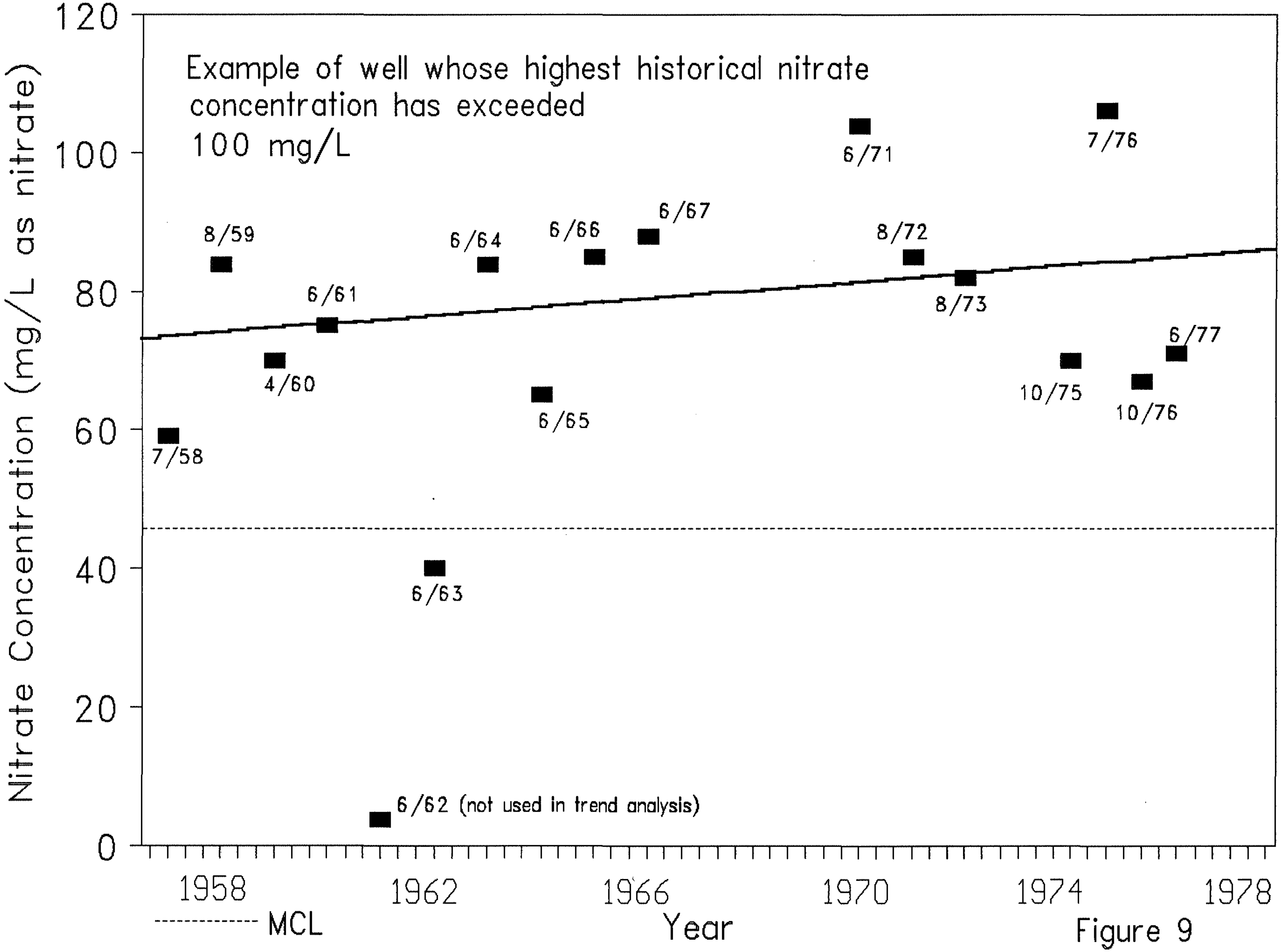
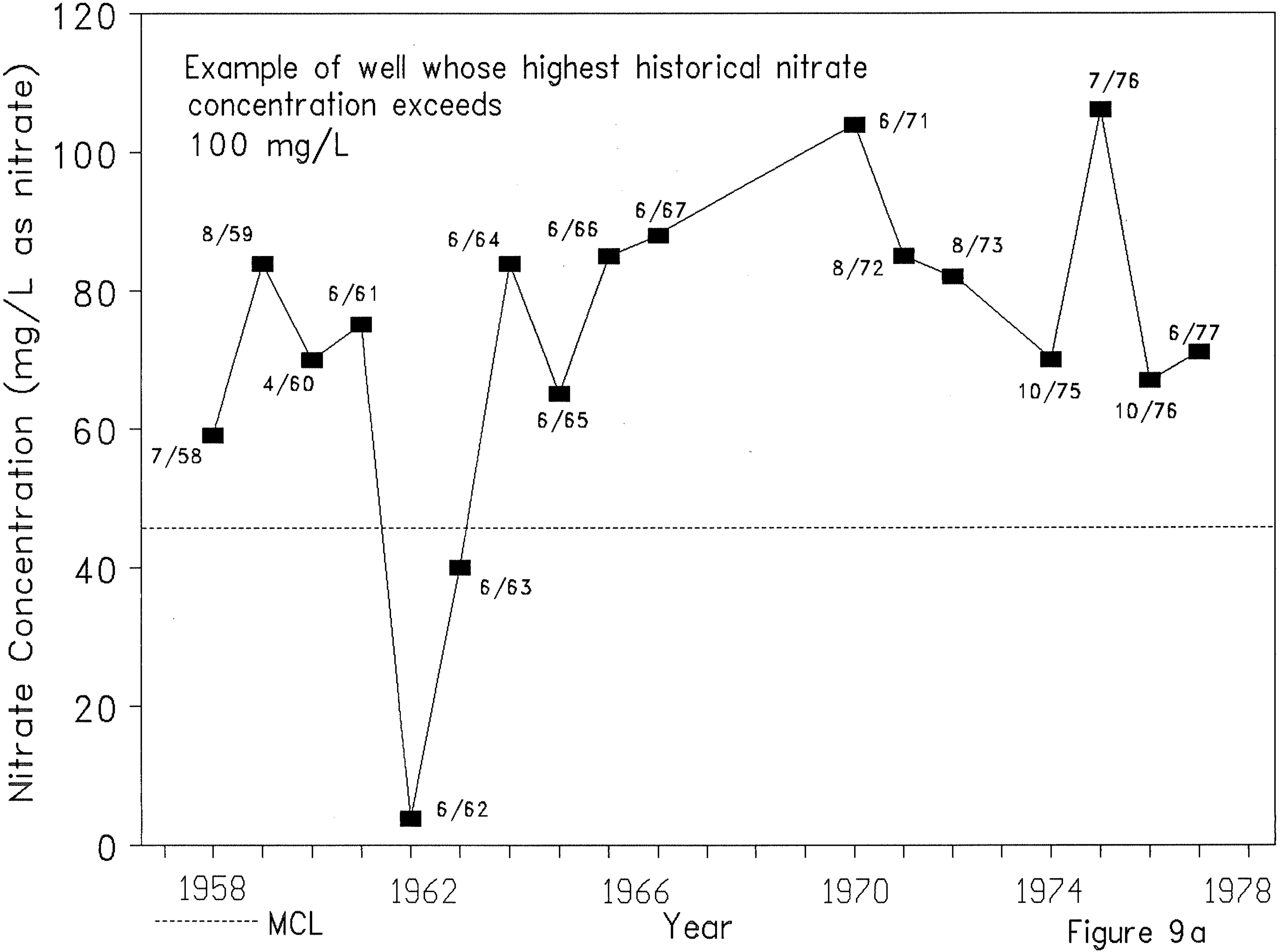


Figure 9



Nitrate Trends in Well #11S4E04Q3

Figure 9a

NOTES ON FIGURES 10-13 :WELL WATER NITRATE CONCENTRATION MAPS

The base map with valley floor boundaries and confined zone boundary was obtained from the Santa Clara Valley Water District map entitled ''Groundwater Level Monitoring Wells—Santa Clara Valley, South County,'' June 1992.

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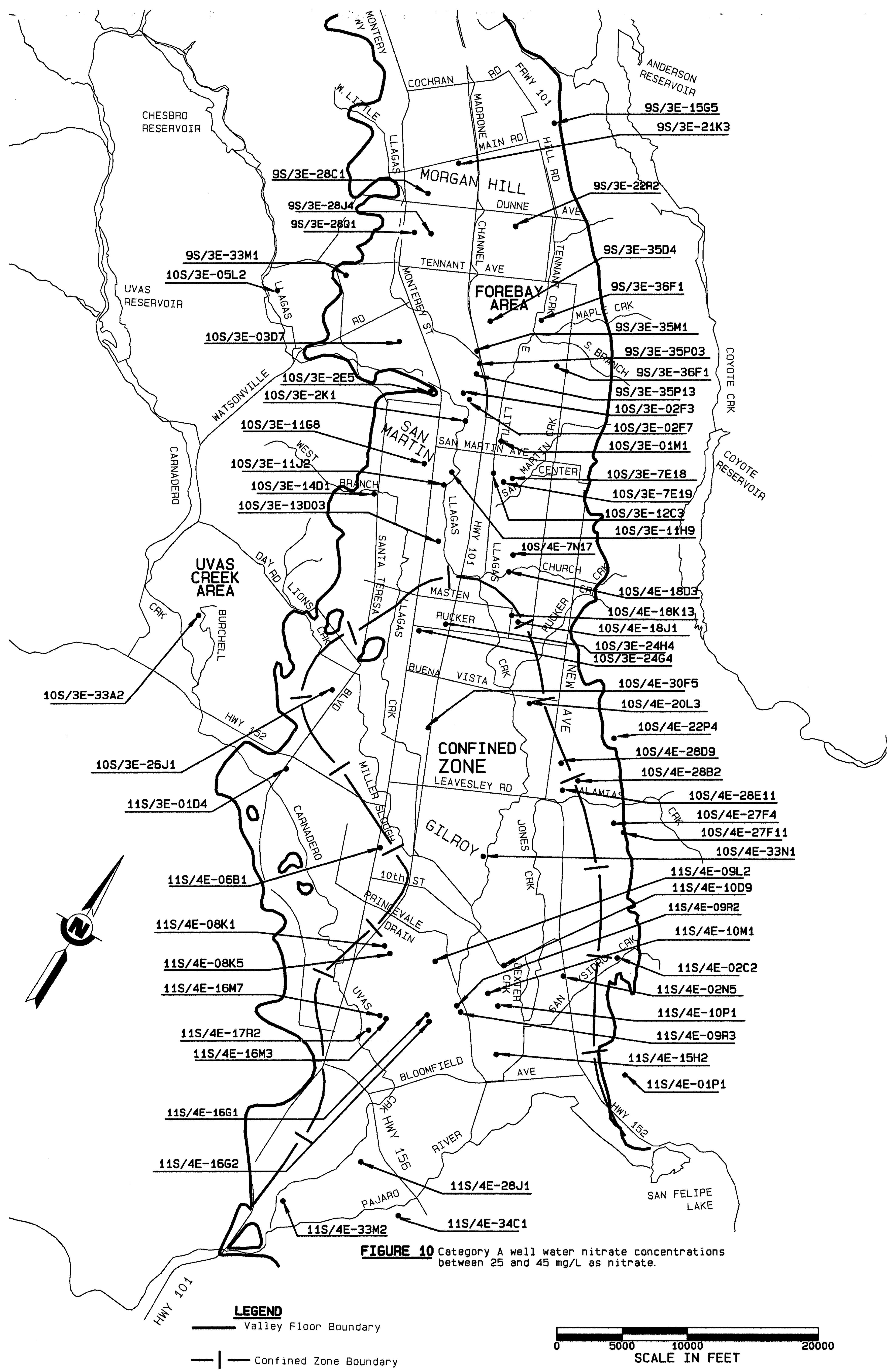

FIGURE 10 Category A well water nitrate concentrations between 25 and 45 mg/L as nitrate.

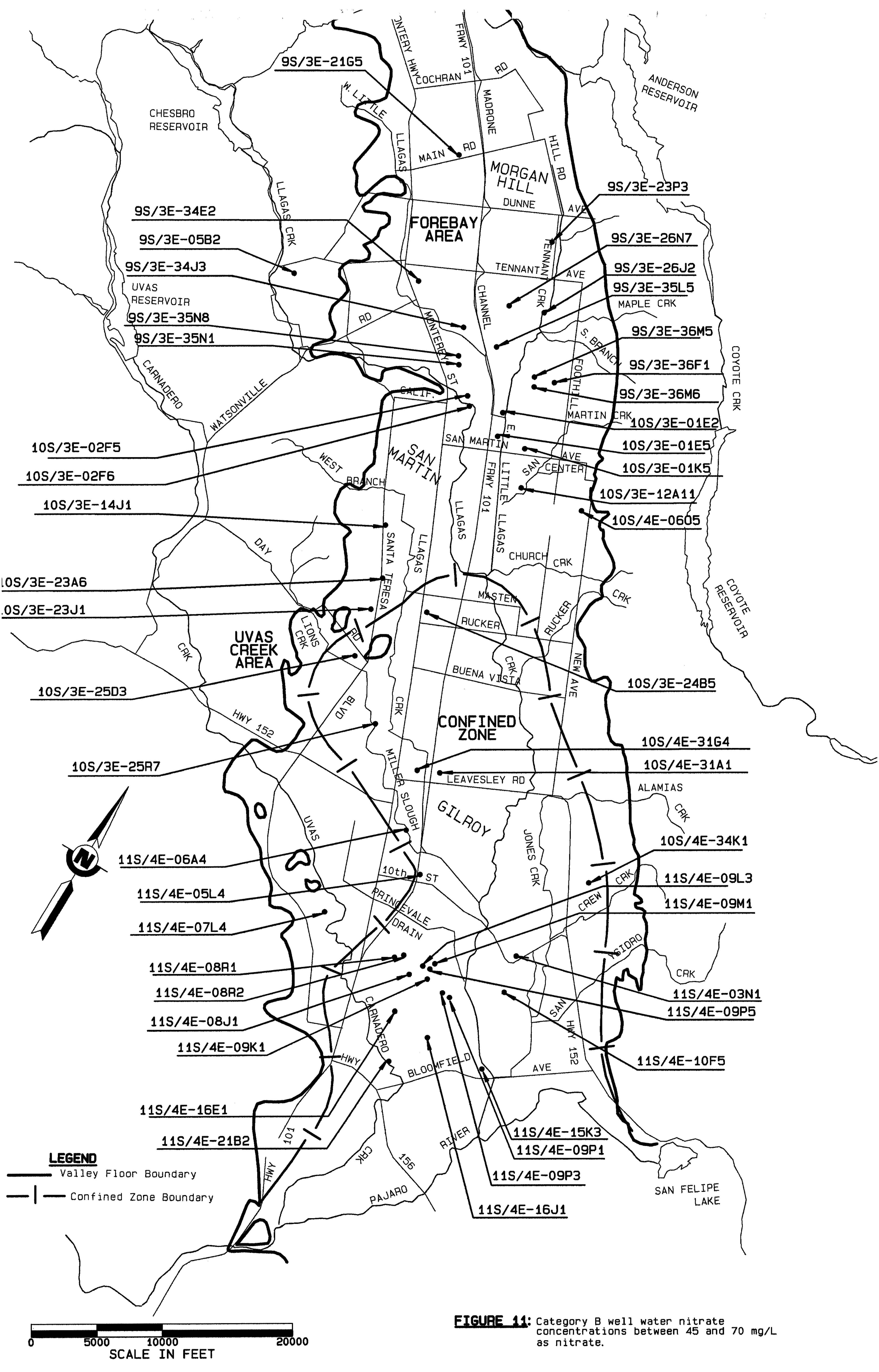

FIGURE 11: Category B well water nitrate concentrations between 45 and 70 mg/L as nitrate.

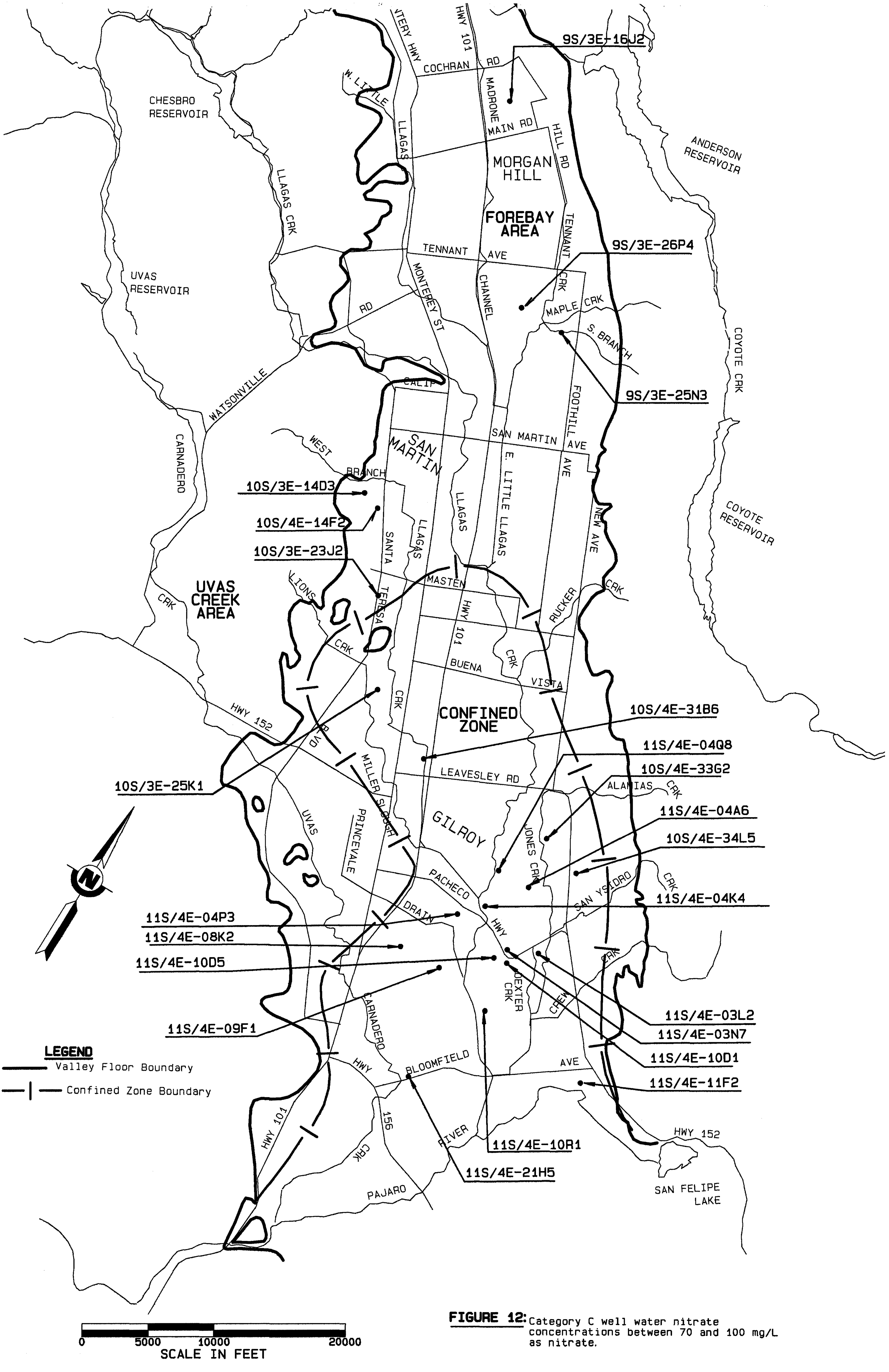

FIGURE 12: Category C well water nitrate concentrations between 70 and 100 mg/L as nitrate.

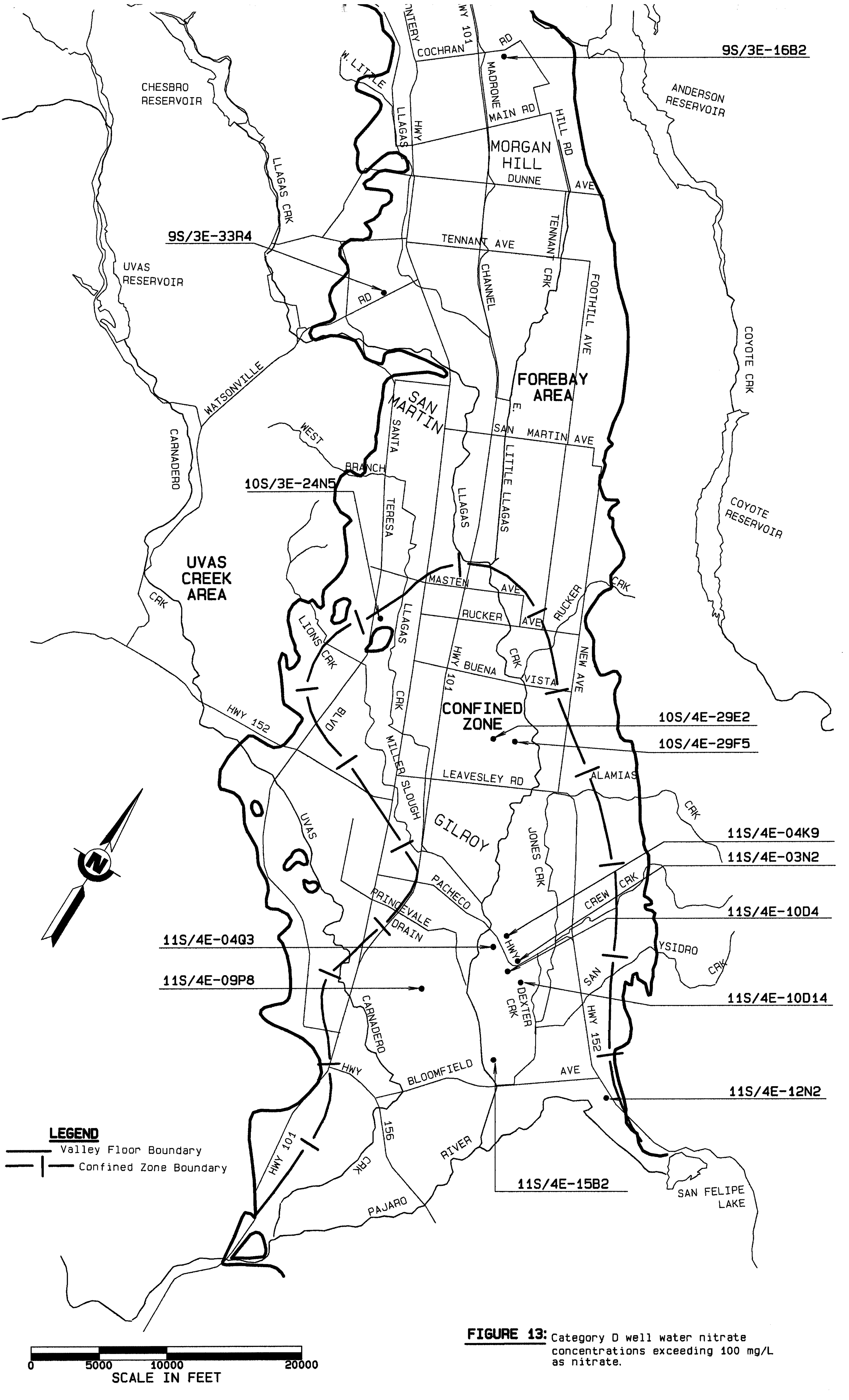

FIGURE 13: Category D well water nitrate concentrations exceeding 100 mg/L as nitrate.